SPECIFICATION

TITLE OF THE INVENTION

ZOOM LENS SYSTEM, AND IMAGE PICKUP SYSTEM USING THE SAME

This application claims benefit of Japanese

5   Application(s) No. Hei 11-322452 filed in Japan on

11/12/1999, the contents of which are incorporated by this

reference.

BACKGROUND OF THE INVENTION

The present invention relates generally to a zoom lens

10   system and an image pickup system using the same, and more

particularly to a zoom lens system suitable for video cameras

or electronic still cameras using electronic image pickup

devices such as CCDs or CMOSs and an image pickup system

using the same.

15   Among zoom lens systems so far known to be suitable for

use ON cameras using electronic image pickup devices, there

is an optical system which comprises, in order from an object

side thereof, a first lens group having negative power, a

second lens group having positive power and a third lens

20   group having positive power together with filters having a

low-pass filter function, etc., and image pickup devices, and

in which zooming is carried out by moving the first and

second lens groups on the optical axis while varying the

spacing between adjacent lens groups.

25   With an increase in the number of pixels in recently

developed electronic image pickup devices such as CCDs or

CMOSs, on the other hand, there are growing demands for a

zoom lens system having ever-higher image-formation

capability, a zoom lens system having an ever-higher zoom ratio and a zoom lens system having an ever-wider field angle on the wide-angle side in particular.

Size reductions of image pickup devices and a more
5   increased number of pixels cause a decrease in the light sensing areas of individual pixels, resulting in strong demands for a lens system having a smaller F-number than ever before.

For a zoom lens system having a field angle (2ω) of the
10   order of 60° to 67° on the wide-angle side, a zoom ratio of the order of 3 and an F-number of the order of 2, some proposals have already been made, as disclosed in JP-A's 11-23967 and 11-52246. However, this is still less than satisfactory in terms of the magnitude of field angle and
15   distortion at the wide-angle end. A zoom lens system having a field angle (2ω) exceeding 70° on the wide-angle side, too, is put forward, as disclosed in JP-A's 11-174322 and 10-39214. However, this leaves much to be desired in terms of F-number. Zoom lens systems disclosed in JP-A's 10-39214 and
20   9-21950 are still unsatisfactory in terms of distortion, etc.

Generally, correction of off-axis aberrations and especially distortion and chromatic aberrations of magnification becomes difficult with an increasing field angle, and correction of spherical aberrations and coma
25   becomes difficult with a decreasing F-number.

SUMMARY OF THE INVENTION

In view of such states of the prior art as explained above, one object of the present invention is to provide a

zoom lens system having a zoom ratio of about 3, a wide field angle on its wide-angle side and a small F-number as well as a lens layout enabling satisfactory image-formation capability to be obtained. Another object of the invention

5   is to provide a lens layout with emphasis placed on fabrication capability.

According to the first aspect of the present invention, these objects are achievable by the provision of a zoom lens system comprising, in order from an object side of said zoom

10 lens system, a first lens group having negative power, an aperture stop, a second lens group having positive power and a third lens group having positive power, wherein:

for zooming, said first lens group and said second lens group move on an optical axis with a varying spacing between

15 adjacent lens groups while said third lens group remains fixed,

during said zooming, said stop moves in unison with said second lens group,

said first lens group comprises, in order from an object

20 side thereof, a negative lens component, a negative lens component and a positive lens component,

said third lens group consists of one lens element,

said first lens group further comprises a lens element having an aspherical surface that satisfies the following

25 condition (1), and

said third lens group further comprises lens element having an aspherical surface that satisfies the following condition (2):

$$0 < (1/r_{a1} - 1/r_{m1})h_1/(n_{a1} - n_{a1}') < 1 \qquad \cdots \text{(1)}$$

$$-1 < (1/r_{a3} - 1/r_{m3})h_3/(n_{a3} - n_{a3}') < 0 \qquad \cdots \text{(2)}$$

where r_{a1} is the paraxial radius of curvature of an aspherical surface I located in said first lens group, r_{m1} is a distance from a point of intersection of an optical axis with said aspherical surface I located in said first lens group to a point on the optical axis where a normal to an arbitrary point (1) between the maximum diameter of an axial light beam on said aspherical surface I and an effective diameter including an off-axis light beam on said aspherical surface I is closest to the optical axis, n_{a1} is the refractive index of said aspherical surface I on an object side thereof, n_{a1}' is the refractive index of said aspherical surface I on an image side thereof, h_1 is the height of said point (1) from the optical axis, r_{a3} is the paraxial radius of curvature of an aspherical surface III located in said third lens group, r_{m3} is a distance from a point of intersection of the optical axis with said aspherical surface III located in said third lens group to a point on the optical axis where a normal to an arbitrary point (3) between the maximum diameter of an axial light beam on said aspherical surface III and an effective diameter including an off-axis light beam on said aspherical surface III is closest to the optical axis, n_{a3} is the refractive index of said aspherical surface III on an object side thereof, n_{a3}' is the refractive index of said aspherical surface III on an image side thereof, and h_3 is the height of said point (3) from the optical axis.

The action and effect of the first zoom lens system according to the present invention are now explained.

By moving the first lens group having negative power and the second lens group having positive power for zooming, it is possible to impart, with simple construction, a wide field angle to the zoom lens system at the wide-angle end in particular, and make the zoom lens system compact while satisfactory performance is kept. With the third lens group having positive power and designed to be fixed during zooming and the aperture stop designed to move in unison with the second lens group for zooming, it is possible to set up an exit pupil position suitable for an electronic image pickup device. In other words, it is possible to locate the exit pupil at a position farther off an image-formation plane with shadings, etc. mind. By the "shadings" are here intended color tone changes (color shading) and rim light quantity changes (shading). For instance, these shadings occur upon oblique incidence of light rays on an image pickup device such as a CCD. This oblique incidence of light occurs depending on the structure of the device, for instance, when color filters and light sensors are positioned in the back of the device, e.g., at a light-shielding portion for a charge transfer path or microlenses are located on the object side of the light-shielding portion for the charge transfer path. To avert this shading problem, it is preferable to locate the exit pupil at a farther position.

To reduce the overall length of the zoom lens system, it is preferable to construct the third lens group of one lens,

because the axial length of the third lens group can be reduced.

The third lens group has a little influence on deterioration of aberrations with respect to axial beams. At the third lens group, however, off-axis light beams and especially astigmatism are likely to occur. By increasing the number of lenses to form the third lens group, image-formation capability may be enhanced depending on the performance, etc. of the image pickup device. In the present invention, however, the third lens group is composed of one positive lens by the introduction of the aspherical surface that satisfies condition (2). By satisfying condition (2), the difference between the center thickness and the peripheral thickness of the lens can be narrowed, thereby reducing the amount of astigmatism produced when the zoom lens system is used on an image pickup device required to have such high image-formation capability as represented by an increased number of pixels. When the upper limit of 0 to condition (2) is exceeded, the aspherical surface loses its own effect, and so fails to reduce astigmatism. Falling below the lower limit of -1 is not preferable, because off-axis beams strike on an image pickup plane from a largely oblique direction with respect to the vertical direction under an adverse influence on a substantial exit pupil position with respect to off-axis beams.

By constructing the first lens group of a negative lens, a negative lens and a positive lens in such a way that the negative lens components are located on the object side, it

is possible to make the outer diameter of the first lens group small. By use of two negative lenses, the amounts of various aberrations produced can be reduced. Especially in the case of a wide-angle yet compact lens layout, an

5 excessive load is applied on the first lens group, resulting in the occurrence of distortion and coma leading to deterioration of performance. By the introduction of the aspherical surface conforming to condition (1) in the first lens group, it is possible to maintain performance. By

10 satisfying condition (1), aberrations produced at the third lens group with respect to off-axis light beams are placed in a well-balanced state. Falling below the lower limit of 0 to condition (1) is not preferable because the aspherical surface loses its own effect. Exceeding the upper limit of 1

15 is not preferable because correction of aberrations throughout the zoom lens system goes out of balance.

According to the second aspect of the present invention, there is provided a zoom lens system comprising, in order from an object side of said zoom lens system, a first lens

20 group having negative power, an aperture stop, a second lens group having positive power and a third lens group having positive power, wherein:

for zooming, said first lens group and said second lens group move on an optical axis with a varying spacing between

25 adjacent lens groups while said third lens group remains fixed,

during said zooming, said stop moves in unison with said second lens group,

said third lens group consists of one lens element, and

said first lens group comprises a lens element obtained

by coating a thin resin on a concave surface of a spherical

lens element satisfying the following condition (3), thereby

5   forming an spherical surface thereon:

$$-0.1 < (1/r_{a1}' - 1/r_{m1})h_1/(n_{a1} - n_{a1}') < 1 \qquad \cdots \ (3)$$

where r_{a1}' is the paraxial radius of curvature of the concave

surface coated thereon with the resin to form an aspherical

surface I located in said first lens group, r_{m1} is a distance

10   from a point of intersection of an optical axis with said

aspherical surface I located in said first lens group to a

point on the optical axis where a normal to an arbitrary

point (1) between the maximum diameter of an axial light beam

on said aspherical surface I and an effective diameter

15   including an off-axis light beam on said aspherical surface I

is closest to the optical axis, n_{a1} is the refractive index of

said aspherical surface I on an object side thereof, n_{a1}' is

the refractive index of said aspherical surface I on an image

side thereof, and h_1 is the height of said point (1) from the

20   optical axis.

The action and effect of the second zoom lens system

according to the present invention are now explained.

By moving the first lens group having negative power and

the second lens group having positive power for zooming, it

25   is possible to impart, with simple construction, a wide field

angle to the zoom lens system at the wide-angle end in

particular, and make the zoom lens system compact while

satisfactory performance is kept. With the third lens group

having positive power and designed to be fixed during zooming and the aperture stop designed to move in unison with the second lens group for zooming, it is possible to set up an exit pupil position suitable for an electronic image pickup

5   device. In other words, it is possible to locate the exit pupil at a position farther off an image-formation plane with shadings, etc. mind. To reduce the overall length of the zoom lens system, it is preferable to construct the third lens group of one lens, because the axial length of the third

10   lens group can be reduced.

Especially in the case of a wide-angle yet compact lens layout, an excessive load is applied on the first lens group, resulting in the occurrence of distortion and coma leading to deterioration of performance. By the introduction of the

15   aspherical surface conforming to condition (1) in the first lens group, it is possible to maintain performance. In this case, it is preferable to use a lens fabricated by coating a thin resin on the concave surface of a spherical lens to form an aspherical surface thereon, because the aspherical surface

20   can be easily formed. In particular, it is preferable to satisfy condition (3). By satisfying condition (3), it is thus possible to form an aspherical surface for the purpose of obtaining satisfactory image-formation capability with no significant change in the thickness of the resin coating.

25   Significant changes in the resin coating are not preferable, because the performance of the resin coating is likely to change due to temperature and humidity changes and any easy solidification of the resin is not achieved during

fabrication. When the lower limit of -0.1 to condition (3)
is not reached, the necessary aspherical performance is not
obtained. Exceeding the upper limit of 1 is not preferable,
because the thickness of the resin coating changes largely.

5   It is here noted that the paraxial radius of curvature of the
concave surface coated with the resin is not always required
to be equal to that of the aspherical surface, although this
is mainly determined in view of fabrication capability, etc.

According to the third aspect of the present invention,
10   there is provided a zoom lens system comprising, in order
from an object side of said zoom lens system, a first lens
group having negative power, an aperture stop, a second lens
group having positive power and a third lens group having
positive power, wherein:

15   for zooming, said first lens group and said second lens
group move on an optical axis with a varying spacing between
adjacent lens groups while said third lens group remains
fixed,

during said zooming, said stop moves in unison with said
20   second lens group,

said first lens group consists of, in order from an
object side thereof, a negative lens component, air, a
negative lens component, air and a positive lens component,

said third lens group consists of one lens element, and
25   said second lens group consists of, in order from an
object side thereof, a positive lens component, a cemented
lens component consisting of a positive element and a
negative element and a positive lens component, and

the following condition (4) is satisfied:

$$0.4 < f_3/f_t < 2.5 \qquad \cdots (4)$$

where f_3 is the focal length of said third lens group and f_t is the focal length of said zoom lens system at a telephoto

5   end thereof.

The action and effect of the third zoom lens system according to the present invention are now explained.

By moving the first lens group having negative power and the second lens group having positive power for zooming, it

10 is possible to impart, with simple construction, a wide field angle to the zoom lens system at the wide-angle end in particular, and make the zoom lens system compact while satisfactory performance is kept. With the third lens group having positive power and designed to be fixed during zooming

15 and the aperture stop designed to move in unison with the second lens group for zooming, it is possible to set up an exit pupil position suitable for an electronic image pickup device. In other words, it is possible to locate the exit pupil at a position farther off an image-formation plane with

20 shadings, etc. mind. To reduce the overall length of the zoom lens system, it is preferable to construct the third lens group of one lens, because the axial length of the third lens group can be reduced.

By constructing the first lens group of a negative lens,

25 a negative lens and a positive lens in such a way that the negative lens components are located on the object side, it is possible to make the outer diameter of the first lens group small. By use of two negative lenses, the amounts of

various aberrations produced can be reduced. Distortion in particular can be reduced by providing an air spacing between adjacent lenses in the first lens group, rather than cementing them together, thereby imparting an independent

5   radius of curvature to each lens.

When the second lens group is comprised of, in order from an object side thereof, a positive lens, a +- cemented lens and a positive lens, it is possible to suppress the occurrence of spherical aberrations and off-axis coma with

10 two positive lenses located in the vicinity of the aperture stop. The second lens group cooperates at its image-side positive lens with the third lens group to gain control of off-axis aberrations while the exit pupil position is spaced away from the image-formation plane, and makes it possible to

15 control chromatic aberrations with the negative lens located between the second positive lens as counted from the object side and the positive lens on the image side. This negative lens, because of being only one negative lens between the aperture stop and the image side, takes some considerable

20 part in correction of aberrations, and so is severely affected by fabrication errors. By cementing this negative lens to the second positive lens, it is possible to achieve an optical system resistant to fabrication errors. It is also possible to prevent higher-order aberrations from

25 occurring between the second lens and the negative lens, thereby achieving more efficient prevention of chromatic aberrations.

By conforming to condition (4), it is possible to achieve satisfactory image-formation capability and take a good exit pupil position while the third lens group is made up of a reduced number of lenses. When the upper limit of 2.5 is exceeded, it is difficult to locate the exit pupil at a farther position while the total length of the zoom lens system is kept short. When the lower limit of 0.4 is not reached, aberrations produced at the third lens group become too large to maintain performance.

According to the fourth aspect of the present invention, there is provided a zoom lens system comprising, in order from an object side of said zoom lens system, a first lens group having negative power, an aperture stop, a second lens group having positive power and a third lens group having positive power, wherein:

for zooming, said first lens group and said second lens group move on an optical axis with a varying spacing between adjacent lens groups while said third lens group remains fixed,

during said zooming, said stop moves in unison with said second lens group,

said first lens group consists of, in order from an object side thereof, a negative lens component, air, a negative lens component, air and a positive lens component,

said third lens group consists of one lens element,

said second lens group consists of, in order from an object side thereof, a positive lens component, a cemented

lens component consisting of a positive element and a
negative element and a positive lens component, and

the following condition (5) is satisfied:

$$1.2 < f_{1-N}/f_{2-N} < 2.7 \qquad \cdots (5)$$

5   where f_{1-N} is the focal length of the negative lens located
nearest to the object side in said first lens group, and f_{2-N}
is the focal length of the second negative lens in said first
lens group, as counted from the object side.

The action and effect of the fourth zoom lens system
10 according to the present invention are now explained.

By moving the first lens group having negative power and
the second lens group having positive power for zooming, it
is possible to impart, with simple construction, a wide field
angle to the zoom lens system at the wide-angle end in
15 particular, and make the zoom lens system compact while
satisfactory performance is kept. With the third lens group
having positive power and designed to be fixed during zooming
and the aperture stop designed to move in unison with the
second lens group for zooming, it is possible to set up an
20 exit pupil position suitable for an electronic image pickup
device. In other words, it is possible to locate the exit
pupil at a position farther off an image-formation plane with
shadings, etc. mind. To reduce the overall length of the
zoom lens system, it is preferable to construct the third
25 lens group of one lens, because the axial length of the third
lens group can be reduced.

By constructing the first lens group of a negative lens,
a negative lens and a positive lens in such a way that the

negative lens components are located on the object side, it
is possible to make the outer diameter of the first lens
group small. By use of two negative lenses, the amounts of
various aberrations produced can be reduced. Distortion in
5   particular can be reduced by providing an air spacing between
adjacent lenses in the first lens group, rather than
cementing them together, thereby imparting an independent
radius of curvature to each lens.

When the second lens group is comprised of, in order
10 from an object side thereof, a positive lens, a +- cemented
lens and a positive lens, it is possible to suppress the
occurrence of spherical aberrations and off-axis coma with
two positive lenses located in the vicinity of the aperture
stop. The second lens group cooperates at its image-side
15 positive lens with the third lens group to control off-axis
aberrations while the exit pupil position is spaced away from
the image-formation plane, and makes it possible to control
chromatic aberrations with the negative lens located between
the second positive lens as counted from the object side and
20 the positive lens on the image side. This negative lens,
because of being only one negative lens between the aperture
stop and the image side, takes some considerable part in
correction of aberrations, and so is severely affected by
fabrication errors. By cementing this negative lens to the
25 second positive lens, it is possible to achieve an optical
system resistant to fabrication errors. It is also possible
to prevent higher-order aberrations from occurring between

the second lens and the negative lens, thereby achieving more efficient prevention of chromatic aberrations.

Condition (5) gives a definition of the power ratio between the first lens and the second lens in the first lens group. An off-axis beam on the wide-angle side in particular has not only a large angle of incidence with respect to the optical axis but also a large angle of incidence with respect to the first surface. The first and second lenses have one function of making the angle of this light beam with respect to the optical axis gentle, using four surfaces. By satisfying condition (5), it is possible to make more efficient use of this function. When the lower limit of 1.2 to condition (5) is not reached, it is difficult to make correction for coma and astigmatism produced at the concave lens located nearest to the object side. When the upper limit of 2.7 is exceeded, aberrations produced at the second concave lens from the object side become too large.

According to the fifth aspect of the present invention, there is provided a zoom lens system comprising, in order from an object side of said zoom lens system, a first lens group having negative power, an aperture stop, a second lens group having positive power and a third lens group having positive power, wherein:

for zooming, said first lens group and said second lens group move on an optical axis with a varying spacing between adjacent lens groups while said third lens group remains fixed,

during said zooming, said stop moves in unison with said
second lens group,

said first lens group consists of, in order from an
object side thereof, a negative lens component, air, a
negative lens component, air and a positive lens component,

said third lens group consists of one lens element,

said second lens group consists of, in order from an
object side thereof, a positive lens component, a cemented
lens component consisting of a positive element and a
negative element and a positive lens component, and

the following condition (6) is satisfied:

$$2 < f_3/IH < 12 \qquad \cdots (6)$$

where f_3 is the focal length of said third lens group, and IH
represents an image height.

The action and effect of the fifth zoom lens system
according to the present invention are now explained.

By moving the first lens group having negative power and
the second lens group having positive power for zooming, it
is possible to impart, with simple construction, a wide field
angle to the zoom lens system at the wide-angle end in
particular, and make the zoom lens system compact while
satisfactory performance is kept. With the third lens group
having positive power and designed to be fixed during zooming
and the aperture stop designed to move in unison with the
second lens group for zooming, it is possible to set up an
exit pupil position suitable for an electronic image pickup
device. In other words, it is possible to locate the exit
pupil at a position farther off an image-formation plane with

shadings, etc. mind. To reduce the overall length of the
zoom lens system, it is preferable to construct the third
lens group of one lens, because the axial length of the third
lens group can be reduced.

5   By constructing the first lens group of a negative lens,
a negative lens and a positive lens in such a way that the
negative lens components are located on the object side, it
is possible to make the outer diameter of the first lens
group small. By use of two separate negative lenses, the
10   amounts of various aberrations produced can be reduced.
Distortion in particular can be reduced by providing an air
spacing between adjacent lenses in the first lens group,
rather than cementing them together, thereby imparting an
independent radius of curvature to each lens.

15   When the second lens group is comprised of, in order
from an object side thereof, a positive lens, a +- cemented
lens and a positive lens, it is possible to suppress the
occurrence of spherical aberrations and off-axis coma with
two positive lenses located in the vicinity of the aperture
20   stop. The second lens group cooperates at its image-side
positive lens with the third lens group to control off-axis
aberrations while the exit pupil position is located farther
off the image-formation plane, and makes it possible to
control chromatic aberrations with the negative lens located
25   between the second positive lens as counted from the object
side and the positive lens on the image side. This negative
lens, because of being only one negative lens between the
aperture stop and the image side, takes some considerable

part in correction of aberrations, and so is severely

affected by fabrication errors. By cementing this negative

lens to the second positive lens, it is possible to achieve

an optical system resistant to fabrication errors. It is

5 also possible to prevent higher-order aberrations from

occurring between the second lens and the negative lens,

thereby achieving more efficient prevention of chromatic

aberrations.

Falling below the lower limit of 2 to condition (6) is

10 not preferable, because the refracting power of the third

lens group with respect to the image height becomes too

strong. This in turn causes the difference between the

center thickness and the peripheral thickness of the positive

lens forming the third lens group to become large, resulting

15 in large off-axis aberrations. Exceeding the upper limit of

12 is again not preferable, because the refracting power of

the third lens group with respect to the image height becomes

too weak. This then makes the aforesaid shadings likely to

occur at an upper portion of the image height if the overall

20 length of the zoom lens system is kept short.

According to the sixth aspect of the present invention,

there is provided a zoom lens system comprising, in order

from an object side of said zoom lens system, a first lens

group having negative power, an aperture stop, a second lens

25 group having positive power and a third lens group having

positive power, wherein:

for zooming, said first lens group and said second lens

group move on an optical axis with a varying spacing between

adjacent lens groups while said third lens group remains fixed,

during said zooming, said stop moves in unison with said second lens group,

5   said first lens group consists of, in order from an object side thereof, a negative lens component, air, a negative lens component, air and a positive lens component,

said third lens group consists of one lens element,

an aspherical surface that satisfies the following

10   condition (7) is used at the surface located nearest to object side in said second lens group, and

the following condition (4) is satisfied:

$$-1 < (1/r_{a2} - 1/r_{m2})h_2/(1 - n_{a2}') < 0 \qquad \cdots (7)$$

$$0.4 < f_3/f_t < 2.5 \qquad \cdots (4)$$

15   where r_{a2} is the paraxial radius of curvature of an aspherical surface II located in said second lens group, r_{m2} is a distance from a point of intersection of an optical axis with said aspherical surface II located in said second lens group to a point on the optical axis where a normal to an arbitrary

20   point (2) between a diameter that is 7/10 of the maximum diameter of an axial light beam on said aspherical surface II and the maximum diameter of the axial beam on said aspherical surface II is closest to the optical axis, n_{a2}' is the refractive index of the lens element located nearest to the

25   object side in said second lens group, h_2 is the height of said point (2) from the optical axis, f_3 is the focal length of said third lens group, and f_t is the focal length of said zoom lens system at a telephoto end thereof.

The action and effect of the sixth zoom lens system according to the present invention are now explained.

By moving the first lens group having negative power and the second lens group having positive power for zooming, it is possible to impart, with simple construction, a wide field angle to the zoom lens system at the wide-angle end in particular, and make the zoom lens system compact while satisfactory performance is kept. With the third lens group having positive power and designed to be fixed during zooming and the aperture stop designed to move in unison with the second lens group for zooming, it is possible to set up an exit pupil position suitable for an electronic image pickup device. In other words, it is possible to locate the exit pupil at a position farther off an image-formation plane with shadings, etc. mind. To reduce the overall length of the zoom lens system, it is preferable to construct the third lens group of one lens, because the axial length of the third lens group can be reduced.

By constructing the first lens group of a negative lens, a negative lens and a positive lens in such a way that the negative lens components are located on the object side, it is possible to make the outer diameter of the first lens group small. By use of two separate negative lenses, the amounts of various aberrations produced can be reduced. Distortion in particular can be reduced by providing an air spacing between adjacent lenses in the first lens group, rather than cementing them together, thereby imparting an independent radius of curvature to each lens.

The surface located nearest to the object side in the second lens group provides not only a surface across which an axial beam spread but also a surface at which an off-axis light beam is close to the optical axis. By locating an

5 aspherical surface on this surface, it is possible to reduce the occurrence of spherical aberrations without having any influence on astigmatism, distortions, etc.

Condition (7) gives a definition of the shape of the aspherical surface. Falling below the lower limit of -1 is

10 not preferable because spherical aberrations remain undercorrected. Exceeding the upper limit of 0 is again not preferable because the effect of the aspherical surface becomes slender and so the overcorrecting state of the spherical lens manifests itself.

15 By conforming to condition (4), it is possible to achieve satisfactory image-formation capability and take a good exit pupil position while the third lens group is made up of a reduced number of lenses. When the upper limit of 2.5 is exceeded, it is difficult to locate the exit pupil at

20 a farther position while the total length of the zoom lens system is kept short. When the lower limit of 0.4 is not reached, aberrations produced at the third lens group become too large to maintain performance.

According to the seventh aspect of the present

25 invention, there is provided a zoom lens system comprising, in order from an object side of said zoom lens system, a first lens group having negative power, an aperture stop, a

second lens group having positive power and a third lens group having positive power, wherein:

for zooming, said first lens group and said second lens group move on an optical axis with a varying spacing between adjacent lens groups while said third lens group remains fixed,

during said zooming, said stop moves in unison with said second lens group,

said first lens group consists of, in order from an object side thereof, a negative lens component, air, a negative lens component, air and a positive lens component,

said third lens group consists of one lens element,

an aspherical surface that satisfies the following condition (7) is used at the surface located nearest to object side in said second lens group, and

the following condition (5) is satisfied:

$$-1 < (1/r_{a2} - 1/r_{m2})h_2/(1 - n_{a2}') < 0 \qquad \cdots \ (7)$$

$$1.2 < f_{1-N}/f_{2-N} < 2.7 \qquad \cdots \ (5)$$

where r_{a2} is the paraxial radius of curvature of an aspherical surface II located in said second lens group, r_{m2} is a distance from a point of intersection of an optical axis with said aspherical surface II located in said second lens group to a point on the optical axis where a normal to an arbitrary point (2) between a diameter that is 7/10 of the maximum diameter of an axial light beam on said aspherical surface II and the maximum diameter of the axial light beam on said aspherical surface II is closest to the optical axis, n_{a2}' is the refractive index of the lens element located nearest to

the object side in said second lens group, h_2 is the height of said point (2) from the optical axis, f_{1-N} is the focal length of the negative lens component located nearest to the object side in said first lens group, and f_{2-N} is the focal length of

5   the second negative lens component in said first lens group, as counted from the object side.

The action and effect of the seventh zoom lens system according to the present invention are now explained.

By moving the first lens group having negative power and

10   the second lens group having positive power for zooming, it is possible to impart, with simple construction, a wide field angle to the zoom lens system at the wide-angle end in particular, and make the zoom lens system compact while satisfactory performance is kept. With the third lens group

15   having positive power and designed to be fixed during zooming and the aperture stop designed to move in unison with the second lens group for zooming, it is possible to set up an exit pupil position suitable for an electronic image pickup device. In other words, it is possible to locate the exit

20   pupil at a position farther off an image-formation plane with shadings, etc. mind. To reduce the overall length of the zoom lens system, it is preferable to construct the third lens group of one lens, because the axial length of the third lens group can be reduced.

25   By constructing the first lens group of a negative lens, a negative lens and a positive lens in such a way that the negative lens components are located on the object side, it is possible to make the outer diameter of the first lens

group small. By use of two separate negative lenses, the amounts of various aberrations produced can be reduced. Distortion in particular can be reduced by providing an air spacing between adjacent lenses in the first lens group,

5   rather than cementing them together, thereby imparting an independent radius of curvature to each lens.

The surface located nearest to the object side in the second lens group provides not only a surface across which an axial beam spread but also a surface at which an off-axis

10   beam is close to the optical axis. By locating an aspherical surface on this surface, it is possible to reduce the occurrence of spherical aberrations without having any influence on astigmatism, distortions, etc.

Condition (7) gives a definition of the shape of the

15   aspherical surface. Falling below the lower limit of -1 is not preferable because spherical aberrations remain undercorrected. Exceeding the upper limit of 0 is again not preferable because the effect of the aspherical surface becomes slender and so the overcorrecting state of the

20   spherical lens manifests itself.

Condition (5) gives a definition of the power ratio between the first lens and the second lens in the first lens group. An off-axis beam on the wide-angle side in particular has not only a large angle of incidence with respect to the

25   optical axis but also a large angle of incidence with respect to the first surface. The first and second lenses have one function of making the angle of this light beam with respect to the optical axis gentle, using four surfaces. By

satisfying condition (5), it is possible to make more efficient use of this function. When the lower limit of 1.2 to condition (5) is not reached, it is difficult to make correction for coma and astigmatism produced at the concave

5 lens located nearest to the object side. When the upper limit of 2.7 is exceeded, aberrations produced at the second concave lens from the object side become too large.

According to the eighth aspect of the present invention, there is provided a zoom lens system comprising, in order

10 from an object side of said zoom lens system, a first lens group having negative power, an aperture stop, a second lens group having positive power and a third lens group having positive power, wherein:

for zooming, said first lens group and said second lens

15 group move on an optical axis with a varying spacing between adjacent lens groups while said third lens group remains fixed,

during said zooming, said stop moves in unison with said second lens group,

20 said first lens group consists of, in order from an object side thereof, a negative lens component, air, a negative lens component, air and a positive lens component,

said third lens group consists of one lens element,

an aspherical surface that satisfies the following

25 condition (7) is used at the surface located nearest to object side in said second lens group, and

the following condition (6) is satisfied:

$$-1 < (1/r_{a2} - 1/r_{m2})h_2/(1 - n_{a2}') < 0 \qquad \cdots (7)$$

$$2 < f_3/IH < 12 \qquad \cdots \ (6)$$

where r_{a2} is the paraxial radius of curvature of an aspherical surface II located in said second lens group, r_{m2} is a distance from a point of intersection of an optical axis with said aspherical surface II located in said second lens group to a point on the optical axis where a normal to an arbitrary point (2) between a diameter that is 7/10 of the maximum diameter of an axial light beam on said aspherical surface II and the maximum diameter of the axial light beam on said aspherical surface II is closest to the optical axis, n_{a2}' is the refractive index of the lens element located nearest to the object side in said second lens group, h_2 is the height of said point (2) from the optical axis, f_3 is the focal length of said third lens group, and IH represents an image height.

The action and effect of the eighth zoom lens system according to the present invention are now explained.

By moving the first lens group having negative power and the second lens group having positive power for zooming, it is possible to impart, with simple construction, a wide field angle to the zoom lens system at the wide-angle end in particular, and make the zoom lens system compact while satisfactory performance is kept. With the third lens group having positive power and designed to be fixed during zooming and the aperture stop designed to move in unison with the second lens group for zooming, it is possible to set up an exit pupil position suitable for an electronic image pickup device. In other words, it is possible to locate the exit pupil at a position farther off an image-formation plane with

shadings, etc. mind. To reduce the overall length of the
zoom lens system, it is preferable to construct the third
lens group of one lens, because the axial length of the third
lens group can be reduced.

5   By constructing the first lens group of a negative lens,
a negative lens and a positive lens in such a way that the
negative lens components are located on the object side, it
is possible to make the outer diameter of the first lens
group small. By use of two separate negative lenses, the

10 amounts of various aberrations produced can be reduced.
Distortion in particular can be reduced by providing an air
spacing between adjacent lenses in the first lens group,
rather than cementing them together, thereby imparting an
independent radius of curvature to each lens.

15   The surface located nearest to the object side in the
second lens group provides not only a surface across which an
axial beam spread but also a surface at which an off-axis
beam is close to the optical axis. By locating an aspherical
surface on this surface, it is possible to reduce the

20 occurrence of spherical aberrations without having any
influence on astigmatism, distortions, etc.

   Condition (7) gives a definition of the shape of the
aspherical surface. Falling below the lower limit of -1 is
not preferable because spherical aberrations remain

25 undercorrected. Exceeding the upper limit of 0 is again not
preferable because the effect of the aspherical surface
becomes slender and so the overcorrecting state of the
spherical lens manifests itself.

Falling below the lower limit of 2 to condition (6) is not preferable, because the refracting power of the third lens group with respect to the image height becomes too strong. This in turn causes the difference between the

5 center thickness and the peripheral thickness of the positive lens forming the third lens group to become large, resulting in large off-axis aberrations. Exceeding the upper limit of 12 is again not preferable, because the refracting power of the third lens group with respect to the image height becomes

10 too weak. This then makes the aforesaid shadings likely to occur at an upper portion of the image height if the overall length of the zoom lens system is kept short.

According to the ninth aspect of the present invention, there is provided a zoom lens system comprising, in order

15 from an object side of said zoom lens system, a first lens group having negative power, an aperture stop, a second lens group having positive power and a third lens group having positive power, wherein:

for zooming, said first lens group and said second lens

20 group move on an optical axis with a varying spacing between adjacent lens groups while said third lens group remains fixed,

during said zooming, said stop moves in unison with said second lens group,

25 lenses forming said first lens group are all defined by meniscus lens components, each convex on an object side thereof, and

the following condition (5) is satisfied:

$$1.2 < f_{1-N}/f_{2-N} < 2.7 \qquad \cdots \quad (5)$$

where f_{1-N} is the focal length of the negative lens component located nearest to the object side in said first lens group, and f_{2-N} is the focal length of the second negative lens

5 component in said first lens group, as counted from the object side.

The action and effect of the ninth zoom lens system according to the present invention are now explained.

By designing the first lens group having negative power

10 and the second lens group having positive power to move for zooming, it is possible to impart, with simple construction, a wide field angle to the zoom lens system at the wide-angle end in particular, and make the zoom lens system compact while satisfactory performance is kept. With the third lens

15 group having positive power and designed to be fixed during zooming and the aperture stop designed to move in unison with the second lens group for zooming, it is possible to set up an exit pupil position suitable for an electronic image pickup device. In other words, it is possible to locate the

20 exit pupil at a position farther off an image-formation plane with shadings, etc. mind. To reduce the overall length of the zoom lens system, it is preferable to construct the third lens group of one lens, because the axial length of the third lens group can be reduced. An off-axis beam on the wide-

25 angle side in particular has not only a large angle of incidence with respect to the optical axis but also a large angle of incidence with respect to the first surface. By using meniscus lenses for the lenses forming the first lens

group, rays in this light beam can be bent little by little at the respective surfaces, so that the amount of aberrations produced can be reduced.

In particular, it is preferable to define the power
5 ratio between the first lens and the second lens in such a way as to satisfy condition (5), because the aforesaid effect can be more enhanced. When the lower limit of 1.2 to condition (5) is not reached, it is difficult to make correction for coma and astigmatism produced at the concave
10 lens located nearest to the object side. When the upper limit of 2.7 is exceeded, aberrations produced at the second concave lens from the object side become too large.

According to the tenth aspect of the present invention, there is provided a zoom lens system comprising, in order
15 from an object side of said zoom lens system, a first lens group having negative power, an aperture stop, a second lens group having positive power and a third lens group having positive power, wherein:

for zooming, said first lens group and said second lens
20 group move on an optical axis with a varying spacing between adjacent lens groups while said third lens group remains fixed,

during said zooming, said stop moves in unison with said second lens group,

25 lenses forming said first lens group are all defined by meniscus lens components, each convex on an object side thereof, and

the following condition (8) is satisfied:

$$-1.35 < f_1/f_3 < -0.4 \qquad \cdots \text{ (8)}$$

where f_1 is the focal length of said first lens group, and f_3 is the focal length of said third lens group.

The action and effect of the tenth zoom lens system
5   according to the present invention are now explained.

By moving the first lens group having negative power and the second lens group having positive power for zooming, it is possible to impart, with simple construction, a wide field angle to the zoom lens system at the wide-angle end in
10   particular, and make the zoom lens system compact while satisfactory performance is kept. With the third lens group having positive power and designed to be fixed during zooming and the aperture stop designed to move in unison with the second lens group for zooming, it is possible to set up an
15   exit pupil position suitable for an electronic image pickup device. In other words, it is possible to locate the exit pupil at a position farther off an image-formation plane with shadings, etc. mind. To reduce the overall length of the zoom lens system, it is preferable to construct the third
20   lens group of one lens, because the axial length of the third lens group can be reduced. An off-axis beam on the wide-angle side in particular has not only a large angle of incidence with respect to the optical axis but also a large angle of incidence with respect to the first surface. By
25   using meniscus lenses for the lenses forming the first lens group, rays in this light beam can be bent little by little at the respective surfaces, so that the amount of aberrations produced can be reduced.

Condition (8) gives a definition of the requirement preferable for locating an exit pupil at a farther position while high zoom ratios and wide field angles are kept. When the upper limit of -0.4 is exceeded, the amount of

5 aberrations produced at the first lens group becomes too large. When the lower limit of -1.35 is not reached, it is impossible to make a reasonable tradeoff between high zoom ratios and size reductions.

According to the eleventh aspect of the present

10 invention, there is provided a zoom lens system comprising, in order from an object side of said zoom lens system, a first lens group having negative power, an aperture stop, a second lens group having positive power and a third lens group having positive power, wherein:

15 for zooming, said first lens group and said second lens group move on an optical axis with a varying spacing between adjacent lens groups while said third lens group remains fixed,

during said zooming, said stop moves in unison with said

20 second lens group,

said third lens group consists of one lens element,

said second lens group consists of, in order from an object side thereof, a positive lens component, a cemented lens component consisting of a positive lens element and a

25 negative lens element and a positive lens component, and

an aspherical surface that satisfies the following condition (7) is used at the surface located nearest to object side in said second lens group:

$$-1 < (1/r_{a2} - 1/r_{m2})h_2/(1 - n_{a2}') < 0 \qquad \cdots (7)$$

where r_{a2} is the paraxial radius of curvature of an aspherical surface II located in said second lens group, r_{m2} is a distance from a point of intersection of an optical axis with

5   said aspherical surface II located in said second lens group to a point on the optical axis where a normal to an arbitrary point (2) between a diameter that is 7/10 of the maximum diameter of an axial light beam on said aspherical surface II and the maximum diameter of the axial light beam on said

10   aspherical surface II is closest to the optical axis, n_{a2}' is the refractive index of the lens element located nearest to the object side in said second lens group, and h_2 is the height of said point (2) from the optical axis.

The action and effect of the eleventh zoom lens system

15   according to the present invention are now explained.

By moving the first lens group having negative power and the second lens group having positive power for zooming, it is possible to impart, with simple construction, a wide field angle to the zoom lens system at the wide-angle end in

20   particular, and make the zoom lens system compact while satisfactory performance is kept. With the third lens group having positive power and designed to be fixed during zooming and the aperture stop designed to move in unison with the second lens group for zooming, it is possible to set up an

25   exit pupil position suitable for an electronic image pickup device. In other words, it is possible to locate the exit pupil at a position farther off an image-formation plane with shadings, etc. mind. To reduce the overall length of the

zoom lens system, it is preferable to construct the third

lens group of one lens, because the axial length of the third

lens group can be reduced. When the second lens group is

comprised of, in order from an object side thereof, a

5   positive lens, a +- cemented lens and a positive lens, it is

possible to suppress the occurrence of spherical aberrations

and off-axis coma with two positive lenses located in the

vicinity of the aperture stop. The second lens group

cooperates at its image-side positive lens with the third

10   lens group to control off-axis aberrations while the exit

pupil position is located farther off the image-formation

plane, and makes it possible to control chromatic aberrations

with the negative lens located between the second positive

lens as counted from the object side and the positive lens on

15   the image side. This negative lens, because of being only

one negative lens between the aperture stop and the image

side, takes some considerable part in correction of

aberrations, and so is severely affected by fabrication

errors. By cementing this negative lens to the second

20   positive lens, it is possible to achieve an optical system

resistant to fabrication errors. It is also possible to

prevent higher-order aberrations from occurring between the

second lens and the negative lens, thereby achieving more

efficient prevention of chromatic aberrations. The surface

25   located nearest to the object side in the second lens group

provides not only a surface across which an axial beam spread

but also a surface at which an off-axis beam is close to the

optical axis. By locating an aspherical surface on this

surface, it is possible to reduce the occurrence of spherical
aberrations without having any influence on astigmatism,
distortions, etc.

Condition (7) gives a definition of the shape of the
5   aspherical surface. Falling below the lower limit of -1 is
not preferable because spherical aberrations remain
undercorrected. Exceeding the upper limit of 0 is again not
preferable because the effect of the aspherical surface
becomes slender and so the overcorrecting state of the
10   spherical lens is reflected as such.

According to the twelfth aspect of the present
invention, there is provided a zoom lens system comprising,
in order from an object side of said zoom lens system, a
first lens group having negative power, an aperture stop, a
15   second lens group having positive power and a third lens
group having positive power, wherein:

for zooming, said first lens group and said second lens
group move on an optical axis with a varying spacing between
adjacent lens groups while said third lens group remains
20   fixed,

during said zooming, said stop moves in unison with said
second lens group,

said third lens group consists of one lens element,

said second lens group consists of, in order from an
25   object side thereof, a positive lens component, a cemented
lens component consisting of a positive lens element and a
negative lens element and a positive lens component while the
lens located nearest to an image plane side in said second

lens group is defined by a meniscus lens component convex on

an image plane side thereof, and

the following condition (9) is satisfied:

$$2.7 < \textstyle\sum_{2g}/IH < 4.7 \qquad \cdots \ (9)$$

5 where $\sum_{2g}$ is a distance on the optical axis from said aperture

stop to the surface located nearest to the image plane side

in said second lens group, and IH represents an image height.

The action and effect of the twelfth zoom lens system

according to the present invention are now explained.

10 By moving the first lens group having negative power and

the second lens group having positive power for zooming, it

is possible to impart, with simple construction, a wide field

angle to the zoom lens system at the wide-angle end in

particular, and make the zoom lens system compact while

15 satisfactory performance is kept. With the third lens group

having positive power and designed to be fixed during zooming

and the aperture stop designed to move in unison with the

second lens group for zooming, it is possible to set up an

exit pupil position suitable for an electronic image pickup

20 device. In other words, it is possible to locate the exit

pupil at a position farther off an image-formation plane with

shadings, etc. mind. To reduce the overall length of the

zoom lens system, it is preferable to construct the third

lens group of one lens, because the axial length of the third

25 lens group can be reduced. When the second lens group is

comprised of, in order from an object side thereof, a

positive lens, a +- cemented lens and a positive lens, it is

possible to suppress ·the occurrence of spherical aberrations

and off-axis coma with two positive lenses located in the vicinity of the aperture stop. The second lens group cooperates at its image-side positive lens with the third lens group to control off-axis aberrations while the exit

5 pupil position is located farther off the image-formation plane, and makes it possible to control chromatic aberrations with the negative lens located between the second positive lens as counted from the object side and the positive lens on the image side. This negative lens, because of being only

10 one negative lens between the aperture stop and the image side, takes some considerable part in correction of aberrations, and so is severely affected by fabrication errors. By cementing this negative lens to the second positive lens, it is possible to achieve an optical system

15 resistant to fabrication errors. It is also possible to prevent higher-order aberrations from occurring between the second positive lens and the negative lens, thereby achieving more efficient prevention of chromatic aberrations. By using a meniscus lens convex on an image plane side thereof for the

20 lens located nearest to the image plane side in the second lens group, it is possible to reduce fluctuations of coma and chromatic aberrations with zooming.

Exceeding the upper limit of 4.7 to condition (9) is not preferable because of an increase in the overall length of

25 the zoom lens system at the telephoto end or during lens collapsing. Falling below the lower limit of 2.7 causes aberrations produced at the second lens group to become larger, and so is not preferable.

According to the thirteenth aspect of the present invention, there is provided a zoom lens system comprising, in order from an object side of said zoom lens system, a first lens group having negative power, an aperture stop, a

5　second lens group having positive power and a third lens group having positive power, wherein:

for zooming, said first lens group and said second lens group move on an optical axis with a varying spacing between adjacent lens groups while said third lens group remains

10　fixed,

during said zooming, said stop moves in unison with said second lens group,

said third lens group consists of one lens element,

said second lens group consists of, in order from an

15　object side thereof, a positive lens component, a cemented lens component consisting of a positive lens element and a negative lens element and a positive lens component while the lens located nearest to an image plane side in said second lens group is defined by a meniscus lens component convex on

20　an image plane side thereof, and

the following condition (4) is satisfied:

$$0.4 < f_3/f_t < 2.5 \qquad \cdots (4)$$

where f_3 is the focal length of said third lens group, and f_t is the focal length of the zoom lens system at a telephoto

25　end thereof.

The action and effect of the thirteenth zoom lens system of the present invention are now explained.

By moving the first lens group having negative power and
the second lens group having positive power for zooming, it
is possible to impart, with simple construction, a wide field
angle to the zoom lens system at the wide-angle end in

5   particular, and make the zoom lens system compact while
satisfactory performance is kept. With the third lens group
having positive power and designed to be fixed during zooming
and the aperture stop designed to move in unison with the
second lens group for zooming, it is possible to set up an

10   exit pupil position suitable for an electronic image pickup
device. In other words, it is possible to locate the exit
pupil at a position farther off an image-formation plane with
shadings, etc. mind. To reduce the overall length of the
zoom lens system, it is preferable to construct the third

15   lens group of one lens, because the axial length of the third
lens group can be reduced. When the second lens group is
comprised of, in order from an object side thereof, a
positive lens, a +- cemented lens and a positive lens, it is
possible to suppress the occurrence of spherical aberrations

20   and off-axis coma with two positive lenses located in the
vicinity of the aperture stop. The second lens group
cooperates at its image-side positive lens with the third
lens group to control off-axis aberrations while the exit
pupil position is located farther off the image-formation

25   plane, and makes it possible to control chromatic aberrations
with the negative lens located between the second positive
lens as counted from the object side and the positive lens on
the image side. This negative lens, because of being only

one negative lens between the aperture stop and the image side, takes some considerable part in correction of aberrations, and so is severely affected by fabrication errors. By cementing this negative lens to the second

5 positive lens, it is possible to achieve an optical system resistant to fabrication errors. It is also possible to prevent higher-order aberrations from occurring between the second positive lens and the negative lens, thereby achieving more efficient prevention of chromatic aberrations. By using

10 a meniscus lens convex on an image plane side thereof for the lens located nearest to the image plane side in the second lens group, it is possible to reduce fluctuations of coma and chromatic aberrations with zooming.

By conforming to condition (4), it is possible to

15 achieve satisfactory image-formation capability and take a good exit pupil position while the third lens group is made up of a reduced number of lenses. When the upper limit of 2.5 is exceeded, it is difficult to locate the exit pupil at a farther position while the total length of the zoom lens

20 system is kept short. When the lower limit of 0.4 is not reached, aberrations produced at the third lens group become too large to maintain performance.

According to the fourteenth aspect of the present invention, there is provided a zoom lens system comprising,

25 in order from an object side of said zoom lens system, a first lens group having negative power, an aperture stop, a second lens group having positive power and a third lens group having positive power, wherein:

for zooming, said first lens group and said second lens group move on an optical axis with a varying spacing between adjacent lens groups while said third lens group remains fixed,

5   during said zooming, said stop moves in unison with said second lens group,

said third lens group consists of one lens element,

said second lens group consists of, in order from an object side thereof, a positive lens component, a cemented

10   lens component consisting of a positive lens element and a negative lens element and a positive lens component while the lens located nearest to an image plane side in said second lens group is defined by a meniscus lens component convex on an image plane side thereof,

15   at least two lens components in said first lens group, as counted from an object side thereof, are defined by negative lens components, and

the following condition (5) is satisfied:

$$1.2 < f_{1-N}/f_{2-N} < 2.7 \qquad \cdots \ (5)$$

20   where f_{1-N} is the focal length of the negative lens component located nearest to the object side in said first lens group, and f_{2-N} is the focal length of the second negative lens component in said first lens group, as counted from the object side.

25   The action and effect of the fourteenth zoom lens system of the present invention are now explained.

By moving the first lens group having negative power and the second lens group having positive power for zooming, it

is possible to impart, with simple construction, a wide field
angle to the zoom lens system at the wide-angle end in
particular, and make the zoom lens system compact while
satisfactory performance is kept. With the third lens group

5   having positive power and designed to be fixed during zooming
and the aperture stop designed to move in unison with the
second lens group for zooming, it is possible to set up an
exit pupil position suitable for an electronic image pickup
device. In other words, it is possible to locate the exit

10   pupil at a position farther off an image-formation plane with
shadings, etc. mind. To reduce the overall length of the
zoom lens system, it is preferable to construct the third
lens group of one lens, because the axial length of the third
lens group can be reduced. When the second lens group is

15   comprised of, in order from an object side thereof, a
positive lens, a +- cemented lens and a positive lens, it is
possible to suppress the occurrence of spherical aberrations
and off-axis coma with two positive lenses located in the
vicinity of the aperture stop. The second lens group

20   cooperates at its image-side positive lens with the third
lens group to control off-axis aberrations while the exit
pupil position is located farther off the image-formation
plane, and makes it possible to control chromatic aberrations
with the negative lens located between the second positive

25   lens as counted from the object side and the positive lens on
the image side. This negative lens, because of being only
one negative lens between the aperture stop and the image
side, takes some considerable part in correction of

aberrations, and so is severely affected by fabrication errors. By cementing this negative lens to the second positive lens, it is possible to achieve an optical system resistant to fabrication errors. It is also possible to

5 prevent higher-order aberrations from occurring between the second positive lens and the negative lens, thereby achieving more efficient prevention of chromatic aberrations. By using a meniscus lens convex on an image plane side thereof for the lens located nearest to the image side in the second lens

10 group, it is possible to reduce fluctuations of coma and chromatic aberrations with zooming.

Condition (5) gives a definition of the power ratio between the first lens and the second lens in the first lens group. An off-axis light beam on the wide-angle side in

15 particular has not only a large angle of incidence with respect to the optical axis but also a large angle of incidence with respect to the first surface. The first and second lenses have one function of making the angle of this light beam with respect to the optical axis gentle, using

20 four surfaces. By satisfying condition (5), it is possible to make more efficient use of this function. When the lower limit of 1.2 to condition (5) is not reached, it is difficult to make correction for coma and astigmatism produced at the concave lens located nearest to the object side. When the

25 upper limit of 2.7 is exceeded, aberrations produced at the second concave lens from the object side become too large.

According to the fifteenth aspect of the present invention, there is provided a zoom lens system comprising,

in order from an object side of said zoom lens system, a first lens group having negative power, an aperture stop, a second lens group having positive power and a third lens group having positive power, wherein:

5   for zooming, said first lens group and said second lens group move on an optical axis with a varying spacing between adjacent lens groups while said third lens group remains fixed,

during said zooming, said stop moves in unison with said
10   second lens group,

said third lens group consists of one lens element,

said second lens group consists of, in order from an object side thereof, a positive lens component, a cemented lens component consisting of a positive lens element and a
15   negative lens element and a positive lens component while the lens located nearest to an image plane side in said second lens group is defined by a meniscus lens component convex on an image plane side thereof, and

the following condition (6) is satisfied:

20                          $2 < f_3/IH < 12$ $\cdots$ (6)

where f_3 is the focal length of said third lens group, and IH represents an image height.

The action and effect of the fifteenth zoom lens system of the present invention are now explained.

25   By moving the first lens group having negative power and the second lens group having positive power for zooming, it is possible to impart, with simple construction, a wide field angle to the zoom lens system at the wide-angle end in

particular, and make the zoom lens system compact while
satisfactory performance is kept. With the third lens group
having positive power and designed to be fixed during zooming
and the aperture stop designed to move in unison with the
5 second lens group for zooming, it is possible to set up an
exit pupil position suitable for an electronic image pickup
device. In other words, it is possible to locate the exit
pupil at a position farther off an image-formation plane with
shadings, etc. mind. To reduce the overall length of the
10 zoom lens system, it is preferable to construct the third
lens group of one lens, because the axial length of the third
lens group can be reduced. When the second lens group is
comprised of, in order from an object side thereof, a
positive lens, a +- cemented lens and a positive lens, it is
15 possible to suppress the occurrence of spherical aberrations
and off-axis coma with two positive lenses located in the
vicinity of the aperture stop. The second lens group
cooperates at its image-side positive lens with the third
lens group to control off-axis aberrations while the exit
20 pupil position is located farther off the image-formation
plane, and makes it possible to control chromatic aberrations
with the negative lens located between the second positive
lens as counted from the object side and the positive lens on
the image side. This negative lens, because of being only
25 one negative lens between the aperture stop and the image
side, takes some considerable part in correction of
aberrations, and so is severely affected by fabrication
errors. By cementing this negative lens to the second

positive lens, it is possible to achieve an optical system resistant to fabrication errors. It is also possible to prevent higher-order aberrations from occurring between the second positive lens and the negative lens, thereby achieving

5   more efficient prevention of chromatic aberrations. By using a meniscus lens convex on an image plane side thereof for the lens located nearest to the image side in the second lens group, it is possible to reduce fluctuations of coma and *chromatic aberrations with zooming.*

10 Falling below the lower limit of 2 to condition (6) is not preferable, because the refracting power of the third lens group with respect to the image height becomes too strong. This in turn causes the difference between the center thickness and the peripheral thickness of the positive

15 lens forming the third lens group to become large, resulting in large off-axis aberrations. Exceeding the upper limit of 12 is again not preferable, because the refracting power of the third lens group with respect to the image height becomes too weak. This then makes the aforesaid shadings likely to

20 occur at an upper portion of the image height if the overall length of the zoom lens system is kept short.

According to the sixteenth aspect of the present invention, there is provided a zoom lens system comprising, in order from an object side of said zoom lens system, a

25 first lens group having negative power, an aperture stop, a second lens group having positive power and a third lens group having positive power, wherein:

for zooming, said first lens group and said second lens group move on an optical axis with a varying spacing between adjacent lens groups while said third lens group remains fixed,

5　　　　during said zooming, said stop moves in unison with said second lens group,

said third lens group consists of one lens element,

said second lens group consists of, in order from an object side thereof, a positive lens component, a cemented

10　lens component consisting of a positive lens element and a negative lens element and a positive lens component,

the thickness ratio between said positive lens element and said negative lens element in said cemented lens component satisfies the following condition (10), and

15　　　　the following condition (4) is satisfied:

$$1.9 < d_{ce1}/d_{ce2} < 12 \qquad \cdots (10)$$
$$0.4 < f_3/f_t < 2.5 \qquad \cdots (4)$$

where d_{ce1} is the thickness on an optical axis of said positive lens element of said cemented lens component in said

20　second lens group, d_{ce2} is the thickness on the optical axis of said negative lens element of said cemented lens component in said second lens group, f_3 is the focal length of said third lens group, and f_t is the focal length of said zoom lens system at a telephoto end thereof.

25　　　　The action and effect of the sixteenth zoom lens system of the present invention are now explained.

By moving the first lens group having negative power and the second lens group having positive power for zooming, it

is possible to impart, with simple construction, a wide field

angle to the zoom lens system at the wide-angle end in

particular, and make the zoom lens system compact while

satisfactory performance is kept. With the third lens group

5   having positive power and designed to be fixed during zooming

and the aperture stop designed to move in unison with the

second lens group for zooming, it is possible to set up an

exit pupil position suitable for an electronic image pickup

device. In other words, it is possible to locate the exit

10   pupil at a position farther off an image-formation plane with

shadings, etc. mind. To reduce the overall length of the

zoom lens system, it is preferable to construct the third

lens group of one lens, because the axial length of the third

lens group can be reduced. When the second lens group is

15   comprised of, in order from an object side thereof, a

positive lens, a +- cemented lens and a positive lens, it is

possible to suppress the occurrence of spherical aberrations

and off-axis coma with two positive lenses located in the

vicinity of the aperture stop. The second lens group

20   cooperates at its image-side positive lens with the third

lens group to control off-axis aberrations while the exit

pupil position is located farther off the image-formation

plane, and makes it possible to control chromatic aberrations

with the negative lens located between the second positive

25   lens as counted from the object side and the positive lens on

the image side. This negative lens, because of being only

one negative lens between the aperture stop and the image

side, takes some considerable part in correction of

aberrations, and so is severely affected by fabrication errors. By cementing this negative lens to the second positive lens, it is possible to achieve an optical system resistant to fabrication errors. It is also possible to

5 prevent higher-order aberrations from occurring between the second positive lens and the negative lens, thereby achieving more efficient prevention of chromatic aberrations.

By determining the thickness ratio between the positive lens and the negative lens cemented thereto in such a way as

10 to satisfy condition (10), it is easy to make a reasonable tradeoff between compactness and prevention of the occurrence of astigmatism in particular. Falling below the lower limit of 1.9 to condition (10) renders correction of astigmatism difficult and so is not preferable. Exceeding the upper

15 limit of 12 is again not preferable, because the cemented lens becomes too thick to achieve compactness.

By conforming to condition (4), it is possible to achieve satisfactory image-formation capability and take a good exit pupil position while the third lens group is made

20 up of a reduced number of lenses. When the upper limit of 2.5 is exceeded, it is difficult to locate the exit pupil at a farther position while the total length of the zoom lens system is kept short. When the lower limit of 0.4 is not reached, aberrations produced at the third lens group become

25 too large to maintain performance.

According to the seventeenth aspect of the present invention, there is provided a zoom lens system comprising, in order from an object side of said zoom lens system, a

first lens group having negative power, an aperture stop, a
second lens group having positive power and a third lens
group having positive power, wherein:

for zooming, said first lens group and said second lens

5   group move on an optical axis with a varying spacing between
adjacent lens groups while said third lens group remains
fixed,

during said zooming, said stop moves in unison with said
second lens group,

10   said third lens group consists of one lens element,

said second lens group consists of, in order from an
object side thereof, a positive lens component, a cemented
lens component consisting of a positive lens element and a
negative lens element and a positive lens component,

15   the thickness ratio between said positive lens element
and said negative lens element in said cemented lens
component satisfies the following condition (10),

at least two lens components nearest to the object side
in said first lens group are defined by negative lens

20   components, and

the following condition (5) is satisfied:

$$1.9 < d_{ce1}/d_{ce2} < 12 \qquad \cdots (10)$$
$$1.2 < f_{1-N}/f_{2-N} < 2.7 \qquad \cdots (5)$$

where d_{ce1} is the thickness on an optical axis of said

25   positive lens element of said cemented lens component in said
second lens group, d_{ce2} is the thickness on the optical axis
of said negative lens element of said cemented lens component
in said second lens group, f_{1-N} is the focal length of the

negative lens component located nearest to the object side in said first lens group, and f_{2-N} is the focal length of the second negative lens component in said first lens group, as counted from the object side.

5   The action and effect of the seventeenth zoom lens system of the present invention are now explained.

By moving the first lens group having negative power and the second lens group having positive power for zooming, it is possible to impart, with simple construction, a wide field 10   angle to the zoom lens system at the wide-angle end in particular, and make the zoom lens system compact while satisfactory performance is kept. With the third lens group having positive power and designed to be fixed during zooming and the aperture stop designed to move in unison with the 15   second lens group for zooming, it is possible to set up an exit pupil position suitable for an electronic image pickup device. In other words, it is possible to locate the exit pupil at a position farther off an image-formation plane with shadings, etc. mind. To reduce the overall length of the 20   zoom lens system, it is preferable to construct the third lens group of one lens, because the axial length of the third lens group can be reduced. When the second lens group is comprised of, in order from an object side thereof, a positive lens, a +- cemented lens and a positive lens, it is 25   possible to suppress the occurrence of spherical aberrations and off-axis coma with two positive lenses located in the vicinity of the aperture stop. The second lens group cooperates at its image-side positive lens with the third

lens group to control off-axis aberrations while the exit
pupil position is located farther off the image-formation
plane, and makes it possible to control chromatic aberrations
with the negative lens located between the second positive

5   lens as counted from the object side and the positive lens on
the image side. This negative lens, because of being only
one negative lens between the aperture stop and the image
side, takes some considerable part in correction of
aberrations, and so is severely affected by fabrication

10 errors. By cementing this negative lens to the second
positive lens, it is possible to achieve an optical system
resistant to fabrication errors. It is also possible to
prevent higher-order aberrations from occurring between the
second positive lens and the negative lens, thereby achieving

15 more efficient prevention of chromatic aberrations.

By determining the thickness ratio between the positive
lens and the negative lens cemented thereto in such a way as
to satisfy condition (10), it is easy to make a reasonable
tradeoff between compactness and prevention of the occurrence

20 of astigmatism in particular. Falling below the lower limit
of 1.9 to condition (10) renders correction of astigmatism
difficult and so is not preferable. Exceeding the upper
limit of 12 is again not preferable, because the cemented
lens becomes too thick to achieve compactness.

25 According to the eighteenth aspect of the present
invention, there is provided a zoom lens system comprising,
in order from an object side of said zoom lens system, a
first lens group having negative power, an aperture stop, a

second lens group having positive power and a third lens group having positive power, wherein:

for zooming, said first lens group and said second lens group move on an optical axis with a varying spacing between

5   adjacent lens groups while said third lens group remains fixed,

during said zooming, said stop moves in unison with said second lens group,

said third lens group consists of one lens element,

10   said second lens group consists of, in order from an object side thereof, a positive lens component, a cemented lens component consisting of a positive lens element and a negative lens element and a positive lens component,

the thickness ratio between said positive lens element

15   and said negative lens element in said cemented lens component satisfies the following condition (10), and

the following condition (6) is satisfied:

$$1.9 < d_{ce1}/d_{ce2} < 12 \qquad \cdots (10)$$

$$3 < f_3/IH < 12 \qquad \cdots (6)$$

20   where d_{ce1} is the thickness on an optical axis of said positive lens element of said cemented lens component in said second lens group, d_{ce2} is the thickness on an optical axis of said negative lens element of said cemented lens component in said second lens group, f_3 is the focal length of said third

25   lens group, and IH represents an image height.

The action and effect of the eighteenth zoom lens system of the present invention are now explained.

By moving the first lens group having negative power and the second lens group having positive power for zooming, it is possible to impart, with simple construction, a wide field angle to the zoom lens system at the wide-angle end in

5 particular, and make the zoom lens system compact while satisfactory performance is kept. With the third lens group having positive power and designed to be fixed during zooming and the aperture stop designed to move in unison with the second lens group for zooming, it is possible to set up an

10 exit pupil position suitable for an electronic image pickup device. In other words, it is possible to locate the exit pupil at a position farther off an image-formation plane with shadings, etc. mind. To reduce the overall length of the zoom lens system, it is preferable to construct the third

15 lens group of one lens, because the axial length of the third lens group can be reduced. When the second lens group is comprised of, in order from an object side thereof, a positive lens, a +- cemented lens and a positive lens, it is possible to suppress the occurrence of spherical aberrations

20 and off-axis coma with two positive lenses located in the vicinity of the aperture stop. The second lens group cooperates at its image-side positive lens with the third lens group to control off-axis aberrations while the exit pupil position is located farther off the image-formation

25 plane, and makes it possible to control chromatic aberrations with the negative lens located between the second positive lens as counted from the object side and the positive lens on the image side. This negative lens, because of being only

one negative lens between the aperture stop and the image
side, takes some considerable part in correction of
aberrations, and so is severely affected by fabrication
errors. By cementing this negative lens to the second
5   positive lens, it is possible to achieve an optical system
resistant to fabrication errors. It is also possible to
prevent higher-order aberrations from occurring between the
second positive lens and the negative lens, thereby achieving
more efficient prevention of chromatic aberrations.

10   By determining the thickness ratio between the positive
lens and the negative lens cemented thereto in such a way as
to satisfy condition (10), it is easy to make a reasonable
tradeoff between compactness and prevention of the occurrence
of astigmatism in particular. Falling below the lower limit
15   of 1.9 to condition (10) renders correction of astigmatism
difficult and so is not preferable. Exceeding the upper
limit of 12 is again not preferable, because the cemented
lens becomes too thick to achieve compactness.

        Falling below the lower limit of 2 to condition (6) is
20   not preferable, because the refracting power of the third
lens group with respect to the image height becomes too
strong. This in turn causes the difference between the
center thickness and the peripheral thickness of the positive
lens forming the third lens group to become large, resulting
25   in large off-axis aberrations. Exceeding the upper limit of
12 is again not preferable, because the refracting power of
the third lens group with respect to the image height becomes
too weak. This then makes the aforesaid shadings likely to

occur at an upper portion of the image height if the overall length of the zoom lens system is kept short.

According to the nineteenth aspect of the present invention, there is provided a zoom lens system comprising,

5   in order from an object side of said zoom lens system, a first lens group having negative power, an aperture stop, a second lens group having positive power and a third lens group having positive power, wherein:

for zooming, said first lens group and said second lens

10   group move on an optical axis with a varying spacing between adjacent lens groups while said third lens group remains fixed,

during said zooming, said stop moves in unison with said second lens group,

15   said first lens group consists of, in order from an object side thereof, a negative lens component, a negative lens component and a positive lens component, and

said third lens group consists of one lens element having on the object side an aspherical surface that

20   satisfies the following condition (2):

$$-1 < (1/r_{a3} - 1/r_{m3})h_3/(n_{a3} - n_{a3}') < 0 \qquad \cdots (2)$$

where r_{a3} is the paraxial radius of curvature of an aspherical surface III located in said third lens group, r_{m3} is a distance from a point of intersection of the optical axis

25   with said aspherical surface III located in said third lens group to a point on the optical axis where a normal to an arbitrary point (3) between the maximum diameter of an axial light beam on said aspherical surface III and an effective

diameter including an off-axis light beam said aspherical surface III is closest to the optical axis, n_{a3} is the refractive index of said aspherical surface III on an object side thereof, n_{a3}' is the refractive index of said aspherical

5   surface III on an image side thereof, and h_3 is the height of said point (3) from the optical axis.

The action and effect of the nineteenth zoom lens system according to the present invention are now explained.

By moving the first lens group having negative power and

10   the second lens group having positive power for zooming, it is possible to impart, with simple construction, a wide field angle to the zoom lens system at the wide-angle end in particular, and make the zoom lens system compact while satisfactory performance is kept. With the third lens group

15   having positive power and designed to be fixed during zooming and the aperture stop designed to move in unison with the second lens group for zooming, it is possible to set up an exit pupil position suitable for an electronic image pickup device. In other words, it is possible to locate the exit

20   pupil at a position farther off an image-formation plane with shadings, etc. mind. To reduce the overall length of the zoom lens system, it is preferable to construct the third lens group of one lens, because the axial length of the third lens group can be reduced.

25   The third lens group has a little influence on deterioration of aberrations with respect to axial beams. At the third lens group, however, off-axis beams and especially astigmatism are likely to occur. By increasing the number of

lenses to form the third lens group, image-formation

capability may be enhanced depending on the performance, etc.

of the image pickup device. In the present invention,

however, the third lens group is composed of one positive

5   lens by the introduction of the aspherical surface that

satisfies condition (2). By satisfying condition (2), the

difference between the center thickness and peripheral

thickness of the lens can be narrowed, thereby reducing the

amount of astigmatism produced when the zoom lens system is

10   used on an image pickup device required to have high image-

formation capability as represented by an increased number of

pixels. Especially if the aspherical surface is located on

the object side where an off-axis light beam is at an angle

with respect to the optical axis and the angle of incidence

15   of the off-axis light beam on the lens tends to become large,

correction of astigmatism and coma can then be advantageously

achieved while the overall length of the zoom lens system is

kept short with the exit pupil located at a farther position.

When the upper limit of 0 to condition (2) is exceeded, the

20   aspherical surface loses its own effect, and so fails to

reduce astigmatism. Falling below the lower limit of -1 is

not preferable, because off-axis light beams strike on an

image pickup plane from a largely oblique direction with

respect to the vertical direction under an adverse influence

25   on a substantial exit pupil position with respect to off-axis

light beams.

The symbols used in the aforesaid conditions (1), (2),

(3) and (7) are now defined.

Fig. 13 shows one exemplary shape of aspherical surface

I in the first lens group with explanations of the symbols

used for condition (1) with respect thereto.

For simplification of explanation, here assume that the

5   aspherical surface I is rotationally symmetric. In Fig. 13,

a spherical surface based on the curvature of the aspherical

surface I on the optical axis is indicated by a broken line.

The radius of curvature of this spherical surface corresponds

to the paraxial radius of curvature, r_{a1}, of the aspherical

10   surface I. An arbitrary point on the aspherical surface I

between the maximum diameter A_1 of an axial light beam and an

effective diameter B_1 including an off-axis light beam is

indicated at (1). Then, a normal to a surface from the point

(1) is indicated at L(1). When the aspherical surface I is

15   rotationally symmetric with respect to the optical axis, the

normal L(1) intersects the optical axis at a point, as shown

in Fig. 13. In this case, the distance from the point of

intersection of the aspherical surface I with the optical

axis to the point of intersection of the optical axis with

20   the normal L(1) is defined by r_{m1}. The height from the

optical axis to the point (1) is defined by h_1, as shown.

As mentioned above, the aspherical surface I is assumed

to be rotationally symmetric with respect to the optical

axis; however, it is not always required to be rotationally

25   symmetric with respect to the optical axis. For instance,

when the aspherical surface I is a rotationally asymmetric

surface or a rotationally symmetric surface where the optical

axis does not provide an axis of rotational symmetry, the

aforesaid normal L(1) does not intersect the optical axis, and so has a torsional relation thereto. In this case, r_{ml} is defined by the distance from the point of intersection of the optical axis with the aspherical surface I to the "point on

5   the optical axis where the normal L(1) to the point (1) is closest to the optical axis".

More specifically, the aforesaid "point on the optical axis where the normal L(1) to the point (1) is closest to the optical axis" is represented by an arbitrary point on the

10   optical axis in the state where the distance from an arbitrary point on the optical axis to an arbitrary point on the normal L(1) is shortest.

In the range of such definition, it is preferable to satisfy condition (1) as already mentioned.

15   It is here noted that whenever there is an arbitrary point (1) satisfying condition (1), the desired effect is achievable; in other words, it is not required to satisfy condition (1) with respect to all points on the aspherical surface I between the maximum diameter A_1 of the axial light

20   beam and the effective diameter B_1 including an off-axis light beam.

Fig. 14 shows one exemplary shape of aspherical surface III in the third lens group with explanations of the symbols used for condition (2) with respect thereto.

25   Roughly speaking, the same explained with reference to the aspherical surface I holds for III. In Fig. 14, a spherical surface based on the curvature of the aspherical surface III on the optical axis is indicated by a broken

line. The radius of curvature of this spherical surface corresponds to the paraxial radius of curvature, r_{a3}, of the aspherical surface III. An arbitrary point on the aspherical surface III between the maximum diameter A_3 of an axial light

5   beam and an effective diameter B_3 including an off-axis light beam is indicated at (3). Then, a normal to a surface from the point (3) is indicated at L(3). In this case, the distance from the point of intersection of the aspherical surface III with the optical axis to the point of

10   intersection of the optical axis with the normal L(3) is defined by r_{m1}. The height from the optical axis to the point (3) is defined by h_3, as shown.

In this case, too, the aspherical surface III is not always required to be rotationally symmetric with respect to

15   the optical axis. For instance, when the aspherical surface III is provided by a rotationally asymmetric surface or a rotationally symmetric surface where the optical axis does not provide an axis of rotational symmetry, r_{m3} is defined by the distance from the point of intersection of the optical

20   axis with the aspherical surface III to the "point on the optical axis where the normal L(3) to the point (3) is closest to the optical axis".

More specifically, the aforesaid "point on the optical axis where the normal L(3) to the point (3) is closest to the

25   optical axis" is represented by an arbitrary point on the optical axis in the state where the distance from an arbitrary point on the optical axis to an arbitrary point on the normal L(3) is shortest.

In the range of such definition, it is preferable to satisfy condition (2) as already mentioned.

Fig. 15 shows one exemplary shape of aspherical surface II in the second lens group with explanations of the symbols used for condition (7) with respect thereto.

Roughly speaking, the same explained with reference to the aspherical surface I holds for II. In Fig. 15, a spherical surface based on the curvature of the aspherical surface II on the optical axis is indicated by a broken line. The radius of curvature of this spherical surface corresponds to the paraxial radius of curvature, r_{a2}, of the aspherical surface II. An arbitrary point on the aspherical surface II between a diameter C that is 7/10 of the maximum diameter A_2 and the maximum diameter A_2 of an axial light beam is indicated at (2). Then, a normal to a surface from the point (2) is indicated at L(2). In this case, the distance from the point of intersection of the aspherical surface II with the optical axis to the point of intersection of the optical axis with the normal L(2) is defined by r_{m2}. The height from the optical axis to the point (2) is defined by h_2, as shown.

In this case, too, the aspherical surface II is not always required to be rotationally symmetric with respect to the optical axis. For instance, when the aspherical surface II is provided by a rotationally asymmetric surface or a rotationally symmetric surface where the optical axis does not provide an axis of rotational symmetry, r_{m2} is defined by the distance from the point of intersection of the optical axis with the aspherical surface II to the "point on the

optical axis where the normal L(2) to the point (2) is closest to the optical axis".

More specifically, the aforesaid "point on the optical axis where the normal L(2) to the point (2) is closest to the

5 optical axis" is represented by an arbitrary point on the optical axis in the state where the distance from an arbitrary point on the optical axis to an arbitrary point on the normal L(2) is shortest.

In the range of such definition, it is preferable to

10 satisfy condition (7) as already mentioned, because spherical aberrations can be well corrected.

Fig. 16 shows one exemplary construction of aspherical surface I obtained by coating a resin on the concave surface in the first lens group with explanations of symbols used for

15 condition (3) with respect thereto.

Referring to Fig. 16, a broken line shows a concave surface on which a resin is coated to form an aspherical surface I located in the first lens group, with the paraxial radius of curvature of the concave surface being indicated at

20 r_{a1}'. An arbitrary point on the aspherical surface I between the maximum diameter A_1 of an axial light beam and an effective diameter B_1 including an off-axis light beam is indicated at (1). Then, a normal to a surface from the point (1) is indicated at L(1). In this case, the distance from

25 the point of intersection of the aspherical surface I with the optical axis to the point of intersection of the optical axis with the normal L(1) is defined by r_{m1}. The height from the optical axis to the point (1) is defined by h_1, as shown.

In this case, too, the aspherical surface I is not always required to be rotationally symmetric with respect to the optical axis. For instance, when the aspherical surface III is provided by a rotationally asymmetric surface or a

5 rotationally symmetric surface where the optical axis does not provide an axis of rotational symmetry, r_{ml} is defined by the distance from the point of intersection of the optical axis with the aspherical surface I to the "point on the optical axis where the normal L(1) to the point (1) is

10 closest to the optical axis".

More specifically, the aforesaid "point on the optical axis where the normal L(1) to the point (1) is closest to the optical axis" is represented by an arbitrary point on the optical axis in the state where the distance from an

15 arbitrary point on the optical axis to an arbitrary point on the normal L(1) is shortest.

In the range of such definition, it is preferable to satisfy condition (3) as already mentioned.

Still other objects and advantages of the present

20 invention will in part be obvious and will in part be apparent from the specification.

The present invention accordingly comprises the features of construction, combinations of elements, and arrangement of parts which will be exemplified in the construction

25 hereinafter set forth, and the scope of the present invention will be indicated in the claims.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 shows in section Example 1 of the zoom lens system according to the present invention at its wide-angle end.

Fig. 2 shows in section Example 2 of the zoom lens 5 system according to the present invention at its wide-angle end.

Fig. 3 shows in section Example 3 of the zoom lens system according to the present invention at its wide-angle end.

10 Fig. 4 shows in section Example 4 of the zoom lens system according to the present invention at its wide-angle end.

Fig. 5 shows in section Example 5 of the zoom lens system according to the present invention at its wide-angle 15 end.

Fig. 6 shows in section Example 6 of the zoom lens system according to the present invention at its wide-angle end.

Fig. 7 shows in section Example 7 of the zoom lens 20 system according to the present invention at its wide-angle end.

Fig. 8 shows in section Example 8 of the zoom lens system according to the present invention at its wide-angle end.

25 Fig. 9 shows in section Example 9 of the zoom lens system according to the present invention at its wide-angle end.

Fig. 10 shows in section Example 10 of the zoom lens system according to the present invention at its wide-angle end.

Fig. 11 shows in section Example 11 of the zoom lens system according to the present invention at its wide-angle end.

Figs. 12(a), 12(b) and 12(c) are aberration diagrams for Example 1 upon focused at infinity.

Fig. 13 shows one exemplary shape of aspherical surface I in the first lens group with explanations of the symbols used for condition (1) with respect thereto.

Fig. 14 shows one exemplary shape of aspherical surface III in the thrid lens group with explanations of the symbols used for condition (2) with respect thereto.

Fig. 15 shows one exemplary shape of aspherical surface II in the second lens group with explanations of the symbols used for condition (7) with respect thereto.

Fig. 16 shows one exemplary construction of aspherical surface I obtained by coating a resin on the concave surface in the first lens group with explanations of symbols used for condition (3) with respect thereto.

Fig. 17 is a front perspective view of an electronic camera wherein the zoom lens system of the present invention is incorporated in the form of an objective optical system.

Fig. 18 is a rear perspective view of the electronic camera wherein the zoom lens system of the present invention is incorporated in the form of an objective optical system.

Fig. 19 is a sectional view of one exemplary construction of the electronic camera wherein the zoom lens system of the present invention is incorporated in the form of an objective optical system.

5   Fig. 20 is a front perspective view of an uncovered personal computer wherein the zoom lens system of the present invention is incorporated in the form of an objective optical system.

Fig. 21 is a sectional view of a phototaking optical

10   system in the personal computer.

Fig. 22 is a side view of Fig. 20.

Figs. 23(a) and 23(b) are a front and a side view of a portable telephone wherein the zoom lens system of the present invention is incorporated in the form of an objective

15   optical system, and Fig. 23(c) is a sectional view of a phototaking optical system therefor.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Examples 1 to 11 of the zoom lens system according to the present invention are now explained.

20   Figs. 1 to 11 are sectional views illustrative of the lens arrangements of Examples 1 through 11 of the present zoom lens system at their wide-angle ends. Numerical data on each example will be enumerated later. Throughout Figs. 1 to 11, plane-parallel plates are located between the third lens

25   group G3 and the image plane. These are filters such as IR cut filters, low-pass filters, and cover glasses for image pickup devices. These plane-parallel plates are omitted from the numerical data given later.

Example 1 is directed to a zoom lens system having a focal length of 4.386 to 12.642 mm, an F-number of 2.36 to 3.99, a half field angle of 37.9 to 14.4° and an image height of 3.32 mm. As shown in Fig. 1, the first lens group G1 is

5 made up of a negative meniscus lens convex on an object side thereof, a negative meniscus lens convex on an object side thereof, which is coated on a concave surface with a thin resin to form an aspherical surface thereon, and a positive meniscus lens convex on an object side thereof. The second

10 lens group G2 is made up of a stop located on an object side thereof, a double-convex lens, a cemented lens consisting of a double-convex lens and a double-concave lens, and a positive meniscus lens convex on an image plane side thereof. The third lens group G3 is made up of one convex lens. Three

15 aspherical surfaces are used; one for the resin aspherical surface formed on the second negative meniscus lens in the first lens group G1, one for the surface located nearest to the object side in the second lens group G2, and one for the object-side surface of the double-convex lens in the third

20 lens group G3. For zooming the wide-angle end to the telephoto end of the zoom lens system, the first lens group G1 moves from the object side toward the image plane side, and then goes back slightly to the object side, as indicated by arrows. The second lens group G2 moves from the image

25 plane side to the object side. The third lens group G3 remains fixed.

Example 2 is directed to a zoom lens system having a focal length of 4.375 to 12.649 mm, an F-number of 2.83 to

4.62, a half field angle of 37.8 to 15.8° and an image height of 3.32 mm. As shown in Fig. 2, the first lens group G1 is made up of three negative meniscus lenses each convex on an object side thereof and a positive meniscus lens convex on an

5   object side thereof. The second lens group G2 is made up of a stop located on an object side thereof, a double-convex lens, a cemented lens consisting of a double-convex lens and a double-concave lens and a double-convex lens, and the third lens group G3 is made up of one double-convex lens. Three

10   aspherical surfaces are used; one for the image plane-side surface of the third negative meniscus lens in the first lens group G1, one for the surface located nearest to the object side in the second lens group G2, and one for the object-side surface of the double-convex lens in the third lens group G3.

15   For zooming the wide-angle end to the telephoto end of the zoom lens system, the first lens group G1 moves from the object side toward the image plane side, and then goes back slightly to the object side, as indicated by arrows. The second lens group G2 moves from the image plane side to the

20   object side. The third lens group G3 remains fixed.

Example 3 is directed to a zoom lens system having a focal length of 4.374 to 12.649 mm, an F-number of 2.31 to 4.00, a half field angle of 37.9 to 15.8° and an image height of 3.32 mm. As shown in Fig. 3, the first lens group G1 is

25   made up of two negative meniscus lenses each convex on an object side thereof and a positive meniscus lens convex on an object side thereof. The second lens group G2 is made up of a stop located on an object side thereof, a double-convex

lens, a cemented lens consisting of a double-convex lens and a double-concave lens and a positive meniscus lens convex on an object side thereof, and the third lens group G3 is made up of one double-convex lens. Three aspherical surfaces are

5   used; one for the image plane-side surface of the second negative meniscus lens in the first lens group G1, one for the surface located nearest to the object side in the second lens group G2, and one for the object-side surface of the double-convex lens in the third lens group G3. For zooming

10   the wide-angle end to the telephoto end of the zoom lens system, the first lens group G1 moves from the object side toward the image plane side, and then goes back slightly to the object side, as indicated by arrows. The second lens group G2 moves from the image plane side to the object side.

15   The third lens group G3 remains fixed.

Example 4 is directed to a zoom lens system having a focal length of 4.374 to 12.648 mm, an F-number of 2.31 to 4.00, a half field angle of 38.0 to 15.6° and an image height of 3.32 mm. As shown in Fig. 4, the first lens group G1 is

20   made up of two negative meniscus lenses each convex on an object side thereof and a positive meniscus lens convex on an object side thereof. The second lens group G2 is made up of a stop located on an object side thereof, a double-convex lens, a cemented lens consisting of a double-convex lens and

25   a double-concave lens and a double-convex lens, and the third lens group G3 is made up of one double-convex lens. Three aspherical surfaces are used; one for the image plane-side surface of the first negative meniscus lens in the first lens

group G1, one for the surface located nearest to the object side in the second lens group G2, and one for the object-side surface of the double-convex lens in the third lens group G3. For zooming the wide-angle end to the telephoto end of the zoom lens system, the first lens group G1 moves from the object side toward the image plane side, and then goes back slightly to the object side, as indicated by arrows. The second lens group G2 moves from the image plane side to the object side. The third lens group G3 remains fixed.

Example 5 is directed to a zoom lens system having a focal length of 4.387 to 12.643 mm, an F-number of 2.42 to 4.09, a half field angle of 37.9 to 14.9° and an image height of 3.32 mm. As shown in Fig. 5, the first lens group G1 is made up of a negative meniscus lens convex on an object side thereof, a negative meniscus lens convex on an object side thereof, which is coated on a concave surface with a thin resin to form an aspherical surface thereon, and a positive meniscus lens convex on an object side thereof. The second lens group G2 is made up of a stop located on an object side thereof, a double-convex lens, a cemented lens consisting of a double-convex lens and a double-concave lens and a positive meniscus lens convex on an image plane side thereof, and the third lens group G3 is made up of one double-convex lens. Two aspherical surfaces are used; one for the resin aspherical surface formed on the second negative meniscus lens in the first lens group G1, and another for the surface located nearest to the object side in the second lens group G2. For zooming the wide-angle end to the telephoto end of

the zoom lens system, the first lens group G1 moves from the object side toward the image plane side, and then goes back slightly to the object side, as indicated by arrows. The second lens group G2 moves from the image plane side to the

5   object side. The third lens group G3 remains fixed.

Example 6 is directed to a zoom lens system having a focal length of 4.371 to 12.622 mm, an F-number of 2.32 to 4.00, a half field angle of 38.1 to 13.9° and an image height of 3.32 mm. As shown in Fig. 6, the first lens group G1 is

10   made up of two negative meniscus lenses each convex on an object side thereof, a negative meniscus lens convex on an image plane side thereof and a positive meniscus lens convex on an object side thereof. The second lens group G2 is made up of a stop located on an object side thereof, a double-

15   convex lens, a cemented lens consisting of a double-convex lens and a double-concave lens and a positive meniscus lens convex on an object side thereof, and the third lens group G3 is made up of one double-convex lens. Three aspherical surfaces are used; one for the surface located nearest to

20   object side in the second lens group G2, one for the object-side surface of the cemented lens in the second lens group G2, and one for the object-side surface of the double-convex lens in the third lens group G3. For zooming the wide-angle end to the telephoto end of the zoom lens system, the first

25   lens group G1 moves from the object side toward the image plane side, and then goes back slightly to the object side, as indicated by arrows. The second lens group G2 moves from

the image plane side to the object side. The third lens group G3 remains fixed.

Example 7 is directed to a zoom lens system having a focal length of 2.973 to 8.568 mm, an F-number of 2.42 to

5 4.09, a half field angle of 37.9 to 14.4° and an image height of 2.25 mm. As shown in Fig. 7, the first lens group G1 is made up of a negative meniscus lens convex on an object side thereof, a negative meniscus lens convex on an object side thereof, which is coated on a concave surface with a thin

10 resin to form an aspherical surface thereon, and a positive meniscus lens convex on an object side thereof. The second lens group G2 is made up of a stop located on an object side thereof, a double-convex lens, a cemented lens consisting of a double-convex lens and a double-concave lens and a positive

15 meniscus lens convex on an image plane side thereof, and the third lens group G3 is made up of one double-convex lens. Two aspherical surfaces are used; one for the resin aspherical surface formed on the second negative meniscus lens in the first lens group G1, and another for the surface

20 located nearest to the object side in the second lens group G2. For zooming the wide-angle end to the telephoto end of the zoom lens system, the first lens group G1 moves from the object side toward the image plane side, and then goes back slightly to the object side, as indicated by arrows. The

25 second lens group G2 moves from the image plane side to the object side. The third lens group G3 remains fixed.

Example 8 is directed to a zoom lens system having a focal length of 3.293 to 9.524 mm, an F-number of 2.31 to

4.00, a half field angle of 38.0 to 15.6° and an image height
of 2.5 mm. As shown in Fig. 8, the first lens group G1 is
made up of a positive meniscus lens convex on an object side
thereof, a double-concave lens and a positive meniscus lens

5   convex on an object side thereof. The second lens group G2
is made up of a stop located on an object side thereof, a
double-convex lens, a cemented lens consisting of a double-
convex lens and a double-concave lens and a double-convex
lens, and the third lens group G3 is made up of one double-

10   convex lens. Three aspherical surfaces are used; one for the
image plane-side surface of the negative meniscus lens in the
first lens group G1, one for the surface located to the
object side in the second lens group G2, and one for the
object-side surface of the double-convex lens in the third

15   lens group G3. For zooming the wide-angle end to the
telephoto end of the zoom lens system, the first lens group
G1 moves from the object side toward the image plane side,
and then goes back slightly to the object side, as indicated
by arrows. The second lens group G2 moves from the image

20   plane side to the object side. The third lens group G3
remains fixed.

Example 9 is directed to a zoom lens system having a
focal length of 2.378 to 6.854 mm, an F-number of 2.36 to
3.99, a half field angle of 37.9 to 14.4° and an image height

25   of 1.8 mm. As shown in Fig. 9, the first lens group G1 is
made up of a negative meniscus lens convex on an object side
thereof, a negative meniscus lens convex on an object side
thereof, which is coated on a concave surface with a thin

resin to form an aspherical surface thereon, and a positive meniscus lens convex on an object side thereof. The second lens group G2 is made up of a stop located on an object side thereof, a double-convex lens, a cemented lens consisting of

5 a double-convex lens and a double-concave lens and a positive meniscus lens convex on an image plane side thereof, and the third lens group G3 is made up of one double-convex lens. Three aspherical surfaces are used; one for the resin aspherical surface formed on the second negative meniscus

10 lens in the first lens group G1, one for the surface located nearest to the object side in the second lens group G2, and one for the object-side surface of the double-convex lens in the third lens group G3. For zooming the wide-angle end to the telephoto end of the zoom lens system, the first lens

15 group G1 moves from the object side toward the image plane side, and then goes back slightly to the object side, as indicated by arrows. The second lens group G2 moves from the image plane side to the object side. The third lens group G3 remains fixed.

20   Example 10 is directed to a zoom lens system having a focal length of 1.975 to 5.703 mm, an F-number of 2.32 to 4.00, a half field angle of 38.1 to 13.9° and an image height of 1.5 mm. As shown in Fig. 10, the first lens group G1 is made up of two negative meniscus lenses each convex on an

25 object side thereof, a negative meniscus lens convex on an image plane side thereof and a positive meniscus lens convex on an image plane side thereof. The second lens group G2 is made up of a stop located on an object side thereof, a

double-convex lens, a cemented lens consisting of a double-convex lens and a double-concave lens and a positive meniscus lens convex on an object side thereof, and the third lens group G3 is made up of one double-convex lens. Three

5   aspherical surfaces are used; one for the surface located nearest to object side in the second lens group G2, one for the object-side surface of the cemented lens in the second lens group G2, and one for the object-side surface of the double-convex lens in the third lens group G3. For zooming

10 the wide-angle end to the telephoto end of the zoom lens system, the first lens group G1 moves from the object side toward the image plane side, and then goes back slightly to the object side, as indicated by arrows. The second lens group G2 moves from the image plane side to the object side.

15 The third lens group G3 remains fixed.

Example 11 is directed to a zoom lens system having a focal length of 2.635 to 7.620 mm, an F-number of 2.31 to 4.00, a half field angle of 37.9 to 15.8° and an image height of 2.0 mm. As shown in Fig. 11, the first lens group G1 is

20 made up of two negative meniscus lenses each convex on an object side thereof, and a positive meniscus lens convex on an object side thereof. The second lens group G2 is made up of a stop located on an object side thereof, a double-convex lens, a cemented lens consisting of a double-convex lens and

25 a double-concave lens and a positive meniscus lens convex on an object side thereof, and the third lens group G3 is made up of one double-convex lens. Three aspherical surfaces are used; one for the image plane-side surface of the second

negative meniscus lens in the second lens group G1, one for the surface located to the object side in the second lens group G2, and one for the object-side surface of the double-convex lens in the third lens group G3. For zooming the

5   wide-angle end to the telephoto end of the zoom lens system, the first lens group G1 moves from the object side toward the image plane side, and then goes back slightly to the object side, as indicated by arrows. The second lens group G2 moves from the image plane side to the object side. The third lens

10   group G3 remains fixed.

Set out below are the numerical data on each example. The symbols used hereinafter but not hereinbefore have the following meanings:

f is the focal length of the zoom lens system, F_{NO} is an

15   F-number, ω is a half field angle, r_1, r_2, $\cdots$ are the radii of curvature of the respective lens surface, d_1, d_2, $\cdots$ are the spacings between adjacent lens surfaces, n_{d1}, n_{d2}, $\cdots$ the d-line refractive index of the respective lens surfaces, and v_{d1}, v_{d2}, $\cdots$ the d-line Abbe's numbers of the respective

20   lenses. Here let x represent an optical axis provided that the direction of propagation of light is positive and y represent a direction perpendicular to the optical axis. Then, the shape of an aspherical surface is given by

$$x = (y^2/r)/[1+\{1-(K+1)(y/r)^2\}^{1/2}]+A_4y^4+A_6y^6+A_8y^8+A_{10}y^{10}$$

25   where r is a paraxial radius of curvature, K is a conical coefficient, and A_4, A_6, A_8 and A_{10} are the fourth, sixth, eighth and tenth aspherical coefficients, respectively.

Example 1

$$f = 4.386 \sim 7.451 \sim 12.642$$

$$F_{NO} = 2.36 \sim 2.96 \sim 3.99$$

$$\omega = 37.9° \sim 23.7° \sim 14.4°$$

$r_1 =$	30.608	$d_1 =$ 1.10	$n_{d1} = 1.69680$ $\nu_{d1} = 55.53$
$r_2 =$	9.922	$d_2 =$ 2.42	
$r_3 =$	27.009	$d_3 =$ 0.95	$n_{d2} = 1.78590$ $\nu_{d2} = 44.20$
$r_4 =$	8.504	$d_4 =$ 0.10	$n_{d3} = 1.52555$ $\nu_{d3} = 52.45$
$r_5 =$	6.982 (Aspheric)	$d_5 =$ 2.73	
$r_6 =$	12.311	$d_6 =$ 2.23	$n_{d4} = 1.80518$ $\nu_{d4} = 25.42$
$r_7 =$	32.087	$d_7 =$ (Variable)	
$r_8 =$	∞ (Stop)	$d_8 =$ 0.94	
$r_9 =$	30.723 (Aspheric)	$d_9 =$ 1.60	$n_{d5} = 1.60311$ $\nu_{d5} = 60.64$
$r_{10} =$	-12.949	$d_{10} =$ 0.50	
$r_{11} =$	5.242	$d_{11} =$ 3.55	$n_{d6} = 1.61272$ $\nu_{d6} = 58.72$
$r_{12} =$	-89.064	$d_{12} =$ 0.50	$n_{d7} = 1.74077$ $\nu_{d7} = 27.79$
$r_{13} =$	3.847	$d_{13} =$ 2.19	
$r_{14} =$	-20.881	$d_{14} =$ 1.37	$n_{d8} = 1.51633$ $\nu_{d8} = 64.14$
$r_{15} =$	-9.365	$d_{15} =$ (Variable)	
$r_{16} =$	39.137 (Aspheric)	$d_{16} =$ 2.46	$n_{d9} = 1.56384$ $\nu_{d9} = 60.67$
$r_{17} =$	-9.532	$d_{17} =$ 4.20	
$r_{18} =$	∞(Image Plane)		

Zooming Spaces

f	4.386	7.451	12.642
d_7	17.15	6.98	1.00

d_{15}	1.00	5.01	11.77

Aspherical Coefficients

5 th surface

$K = 0.000$

$A_4 = -4.37407 \times 10^{-4}$

$A_6 = 2.95376 \times 10^{-10}$

$A_8 = -1.05245 \times 10^{-7}$

$A_{10} = -2.15246 \times 10^{-9}$

9 th surface

$K = 0.000$

$A_4 = -2.05174 \times 10^{-4}$

$A_6 = -6.60605 \times 10^{-6}$

$A_8 = 8.45958 \times 10^{-7}$

$A_{10} = -3.81345 \times 10^{-8}$

1 6 th surface

$K = 0.000$

$A_4 = -5.57767 \times 10^{-4}$

$A_6 = 1.64691 \times 10^{-5}$

$A_8 = -8.27513 \times 10^{-7}$

$A_{10} = 1.69001 \times 10^{-8}$

Example 2

$$f = 4.375 \sim 7.411 \sim 12.649$$

$$F_{NO} = 2.83 \sim 3.48 \sim 4.62$$

$$\omega = 37.8° \sim 24.1° \sim 15.8°$$

$r_1 = 15.773$ $d_1 = 1.10$ $n_{d1} = 1.69680$ $\nu_{d1} = 55.53$

$r_2 = 9.476$ $d_2 = 1.53$

$r_3 =$ 14.021	$d_3 =$ 1.00	$n_{d2} =$ 1.69680	$\nu_{d2} =$ 55.53
$r_4 =$ 8.058	$d_4 =$ 2.59		
$r_5 =$ 40.949	$d_5 =$ 0.80	$n_{d3} =$ 1.88300	$\nu_{d3} =$ 40.76
$r_6 =$ 7.484 (Aspheric)	$d_6 =$ 2.33		
$r_7 =$ 14.074	$d_7 =$ 2.21	$n_{d4} =$ 1.80518	$\nu_{d4} =$ 25.42
$r_8 =$ 315.362	$d_8 =$ (Variable)		
$r_9 =$ ∞ (Stop)	$d_9 =$ 0.87		
$r_{10} =$ 8.943 (Aspheric)	$d_{10} =$ 2.80	$n_{d5} =$ 1.60311	$\nu_{d5} =$ 60.64
$r_{11} =$ -19.486	$d_{11} =$ 1.74		
$r_{12} =$ 11.249	$d_{12} =$ 3.34	$n_{d6} =$ 1.61272	$\nu_{d6} =$ 58.72
$r_{13} =$ -8.479	$d_{13} =$ 0.50	$n_{d7} =$ 1.74077	$\nu_{d7} =$ 27.79
$r_{14} =$ 5.482	$d_{14} =$ 3.17		
$r_{15} =$ 15.126	$d_{15} =$ 2.29	$n_{d8} =$ 1.60342	$\nu_{d8} =$ 38.03
$r_{16} =$ -48.736	$d_{16} =$ (Variable)		
$r_{17} =$ 12.445 (Aspheric)	$d_{17} =$ 1.39	$n_{d9} =$ 1.56384	$\nu_{d9} =$ 60.67
$r_{18} =$ -250.472	$d_{18} =$ 4.21		
$r_{19} =$ ∞ (Image Plane)			

Zooming Spaces

f	4.375	7.411	12.649
d_8	16.57	6.83	1.00
d_{16}	0.50	5.03	12.82

Aspherical Coefficients

6 th surface

K = 0.000

$A_4 = -3.68865 \times 10^{-4}$

$A_6 = -1.90729 \times 10^{-6}$

$A_8 = -9.53501 \times 10^{-8}$

$A_{10} = 8.24639 \times 10^{-12}$

1 0 th surface

$K = 0.000$

$A_4 = -2.77414 \times 10^{-4}$

$A_6 = 2.77354 \times 10^{-6}$

$A_8 = -4.45517 \times 10^{-7}$

$A_{10} = 1.14044 \times 10^{-8}$

1 7 th surface

$K = 0.000$

$A_4 = -2.92081 \times 10^{-4}$

$A_6 = 1.48703 \times 10^{-5}$

$A_8 = -6.56437 \times 10^{-7}$

$A_{10} = 1.02200 \times 10^{-8}$

Example 3

$$f = 4.374 \sim 7.448 \sim 12.649$$

$$F_{NO} = 2.31 \sim 2.93 \sim 4.00$$

$$\omega = 37.9° \sim 24.0° \sim 15.8°$$

$r_1 = 20.947$	$d_1 = 0.95$	$n_{d1} = 1.69680$	$\nu_{d1} = 55.53$
$r_2 = 6.794$	$d_2 = 3.43$		
$r_3 = 25.746$	$d_3 = 0.70$	$n_{d2} = 1.78590$	$\nu_{d2} = 44.20$
$r_4 = 6.745$ (Aspheric)	$d_4 = 2.48$		
$r_5 = 13.847$	$d_5 = 2.10$	$n_{d3} = 1.80518$	$\nu_{d3} = 25.42$
$r_6 = 102.749$	$d_6 = $(Variable)		
$r_7 = \infty$ (Stop)	$d_7 = 0.70$		

r_8 =   8.691 (Aspheric) d_8 =   3.92 n_{d4} =1.60311 ν_{d4} =60.64

r_9 =   -18.462 d_9 =   0.50

r_{10}=   9.505 d_{10}=   3.45 n_{d5} =1.61272 ν_{d5} =58.72

r_{11}=   -10.051 d_{11}=   0.50 n_{d6} =1.74077 ν_{d6} =27.79

r_{12}=   4.905 d_{12}=   3.42

r_{13}=   15.706 d_{13}=   1.01 n_{d7} =1.60342 ν_{d7} =38.03

r_{14}= 17250.422 d_{14}=(Variable)

r_{15}=   11.303 (Aspheric) d_{15}=   1.78 n_{d8} =1.56384 ν_{d8} =60.67

r_{16}=   -48.249 d_{16}=   3.94

r_{17}=   ∞(Image Plane)

Zooming Spaces

f	4.374	7.448	12.649
d_6	15.02	6.19	1.00
d_{14}	1.00	5.80	13.87

Aspherical Coefficients

4 th surface

K = 0.000

A_4 =-5.75781×10^{-4}

A_6 =-2.01153×10^{-6}

A_8 =-2.60007×10^{-7}

A_{10}=-3.72946×10^{-10}

8 th surface

K = 0.000

A_4 =-2.80524×10^{-4}

$A_6 = -1.61468 \times 10^{-6}$

$A_8 = -1.94898 \times 10^{-8}$

$A_{10} = -1.27601 \times 10^{-10}$

1 5 th surface

$K = 0.000$

$A_4 = -2.70433 \times 10^{-4}$

$A_6 = 1.36913 \times 10^{-5}$

$A_8 = -6.86548 \times 10^{-7}$

$A_{10} = 1.27612 \times 10^{-8}$

Example 4

$f = 4.374 \sim 7.448 \sim 12.648$

$F_{NO} = 2.31 \sim 2.93 \sim 4.00$

$\omega = 38.0° \sim 23.8° \sim 15.6°$

$r_1 = 73.199$	$d_1 = 1.10$	$n_{d1} = 1.69680$	$\nu_{d1} = 55.53$
$r_2 = 13.721$ (Aspheric)	$d_2 = 3.98$		
$r_3 = -1281.699$	$d_3 = 0.95$	$n_{d2} = 1.81600$	$\nu_{d2} = 46.62$
$r_4 = 8.202$	$d_4 = 3.12$		
$r_5 = 14.786$	$d_5 = 2.05$	$n_{d3} = 1.80518$	$\nu_{d3} = 25.42$
$r_6 = 88.390$	$d_6 = $(Variable)		
$r_7 = \infty$ (Stop)	$d_7 = 0.42$		
$r_8 = 23.686$ (Aspheric)	$d_8 = 1.66$	$n_{d4} = 1.60311$	$\nu_{d4} = 60.64$
$r_9 = -16.220$	$d_9 = 0.50$		
$r_{10} = 6.386$	$d_{10} = 4.62$	$n_{d5} = 1.61272$	$\nu_{d5} = 58.72$
$r_{11} = -13.321$	$d_{11} = 0.50$	$n_{d6} = 1.72825$	$\nu_{d6} = 28.46$
$r_{12} = 4.469$	$d_{12} = 2.75$		
$r_{13} = 46.980$	$d_{13} = 1.64$	$n_{d7} = 1.51633$	$\nu_{d7} = 64.14$
$r_{14} = -18.186$	$d_{14} = $(Variable)		

$r_{15}=$ 19.128 (Aspheric) $d_{15}=$ 2.30 $n_{d8} = 1.56384$ $\nu_{d8} = 60.67$

$r_{16}=$ -14.925 $d_{16}=$ 4.19

$r_{17}=$ ∞(Image Plane)

Zooming Spaces

f	4.374	7.448	12.648
d_6	16.12	6.58	1.00
d_{14}	1.00	5.73	13.69

Aspherical Coefficients

   2 nd surface

   $K = 0.000$

   $A_4 = -1.83153 \times 10^{-4}$

   $A_6 = -3.40705 \times 10^{-7}$

   $A_8 = 1.25210 \times 10^{-13}$

   $A_{10} = -9.97522 \times 10^{-12}$

   8 th surface

   $K = 0.000$

   $A_4 = -1.00639 \times 10^{-4}$

   $A_6 = -1.18430 \times 10^{-6}$

   $A_8 = 2.11991 \times 10^{-7}$

   $A_{10} = -9.90194 \times 10^{-9}$

   1 5 th surface

   $K = 0.000$

   $A_4 = -4.01115 \times 10^{-4}$

   $A_6 = 1.35678 \times 10^{-5}$ ·

$A_8 = -6.19449 \times 10^{-7}$

$A_{10} = 1.00098 \times 10^{-8}$

Example 5

$$f = 4.387 \sim 7.451 \sim 12.643$$

$$F_{NO} = 2.42 \sim 3.04 \sim 4.09$$

$$\omega = 37.9° \sim 24.2° \sim 14.9°$$

$r_1 = 20.677$	$d_1 = 1.10$	$n_{d1} = 1.69680$	$\nu_{d1} = 55.53$
$r_2 = 8.565$	$d_2 = 3.49$		
$r_3 = 37.351$	$d_3 = 0.95$	$n_{d2} = 1.81600$	$\nu_{d2} = 46.62$
$r_4 = 9.087$	$d_4 = 0.10$	$n_{d3} = 1.52555$	$\nu_{d3} = 52.45$
$r_5 = 7.102$ (Aspheric)	$d_5 = 3.09$		
$r_6 = 15.013$	$d_6 = 2.20$	$n_{d4} = 1.80518$	$\nu_{d4} = 25.42$
$r_7 = 78.101$	$d_7 =$ (Variable)		
$r_8 = \infty$ (Stop)	$d_8 = 0.96$		
$r_9 = 192.084$ (Aspheric)	$d_9 = 1.47$	$n_{d5} = 1.60311$	$\nu_{d5} = 60.64$
$r_{10} = -12.882$	$d_{10} = 0.50$		
$r_{11} = 6.097$	$d_{11} = 5.24$	$n_{d6} = 1.61272$	$\nu_{d6} = 58.72$
$r_{12} = -9.764$	$d_{12} = 0.50$	$n_{d7} = 1.74077$	$\nu_{d7} = 27.79$
$r_{13} = 4.498$	$d_{13} = 2.15$		
$r_{14} = -58.594$	$d_{14} = 1.47$	$n_{d8} = 1.60342$	$\nu_{d8} = 38.03$
$r_{15} = -11.441$	$d_{15} =$ (Variable)		
$r_{16} = 14.316$	$d_{16} = 2.75$	$n_{d9} = 1.56384$	$\nu_{d9} = 60.67$
$r_{17} = -18.860$	$d_{17} = 4.20$		
$r_{18} = \infty$ (Image Plane)			

Zooming Spaces

f	4.387	7.451	12.643

d_7	17.82	7.23	1.00
d_{15}	1.00	5.63	13.44

Aspherical Coefficients

5 th surface

$K = 0.000$

$A_4 = -5.06617 \times 10^{-4}$

$A_6 = 2.08894 \times 10^{-10}$

$A_8 = -1.83217 \times 10^{-7}$

$A_{10} = -2.12210 \times 10^{-10}$

9 th surface

$K = 0.000$

$A_4 = -1.20398 \times 10^{-4}$

$A_6 = -4.22111 \times 10^{-6}$

$A_8 = 5.21447 \times 10^{-7}$

$A_{10} = -1.71674 \times 10^{-8}$

Example 6

$$f = 4.371 \sim 4.898 \sim 12.622$$

$$F_{NO} = 2.32 \sim 2.42 \sim 4.00$$

$$\omega = 38.1° \sim 24.8° \sim 13.9°$$

$r_1 = 26.445$	$d_1 = 1.10$	$n_{d1} = 1.69680 \quad \nu_{d1} = 55.53$
$r_2 = 11.792$	$d_2 = 2.81$	
$r_3 = 68.200$	$d_3 = 1.00$	$n_{d2} = 1.69680 \quad \nu_{d2} = 55.53$
$r_4 = 14.028$	$d_4 = 3.16$	
$r_5 = -23.225$	$d_5 = 0.90$	$n_{d3} = 1.88300 \quad \nu_{d3} = 40.76$

$r_6 = -4325.882$	$d_6 = 1.34$		
$r_7 = -20.775$	$d_7 = 1.72$	$n_{d4} = 1.80518$	$\nu_{d4} = 25.42$
$r_8 = -11.656$	$d_8 =$ (Variable)		
$r_9 = \infty$ (Stop)	$d_9 = 1.70$		
$r_{10} = 6.001$ (Aspheric)	$d_{10} = 2.03$	$n_{d5} = 1.60311$	$\nu_{d5} = 60.64$
$r_{11} = -18.104$	$d_{11} = 2.19$		
$r_{12} = 132.728$ (Aspheric)	$d_{12} = 1.01$	$n_{d6} = 1.61272$	$\nu_{d6} = 58.72$
$r_{13} = -11.240$	$d_{13} = 0.50$	$n_{d7} = 1.74077$	$\nu_{d7} = 27.79$
$r_{14} = 4.411$	$d_{14} = 1.28$		
$r_{15} = 7.374$	$d_{15} = 1.11$	$n_{d8} = 1.60342$	$\nu_{d8} = 38.03$
$r_{16} = 53.534$	$d_{16} =$ (Variable)		
$r_{17} = 88.907$ (Aspheric)	$d_{17} = 4.56$	$n_{d9} = 1.56384$	$\nu_{d9} = 60.67$
$r_{18} = -8.781$	$d_{18} = 4.35$		
$r_{19} = \infty$ (Image Plane)			

Zooming Spaces

f	4.371	4.898	12.622
d_8	18.99	15.85	1.00
d_{16}	0.50	1.25	11.73

Aspherical Coefficients

1 0 th surface

$K = 0.000$

$A_4 = -6.37232 \times 10^{-4}$

$A_6 = -4.39285 \times 10^{-6}$

$A_8 = -1.16573 \times 10^{-6}$

$A_{10}= 3.24269 \times 10^{-8}$

1 2 th surface

$K = 0.000$

$A_4 = 3.49239 \times 10^{-4}$

$A_6 = -1.39146 \times 10^{-5}$

$A_8 = 3.75806 \times 10^{-6}$

$A_{10}= 5.39048 \times 10^{-9}$

1 7 th surface

$K = 0.000$

$A_4 = -1.22514 \times 10^{-3}$

$A_6 = -1.04830 \times 10^{-5}$

$A_8 = -6.78577 \times 10^{-7}$

$A_{10}= 4.26779 \times 10^{-8}$

Example 7

$f = 2.973 \sim 5.050 \sim 8.568$

$F_{NO}= 2.42 \sim 3.04 \sim 4.09$

$\omega = 37.9° \sim 23.7° \sim 14.4°$

$r_1 = 14.013$	$d_1 = 0.75$	$n_{d1} = 1.69680$	$\nu_{d1} = 55.53$
$r_2 = 5.805$	$d_2 = 2.36$		
$r_3 = 25.313$	$d_3 = 0.64$	$n_{d2} = 1.81600$	$\nu_{d2} = 46.62$
$r_4 = 6.158$	$d_4 = 0.07$	$n_{d3} = 1.52555$	$\nu_{d3} = 52.45$
$r_5 = 4.813$ (Aspheric)	$d_5 = 2.10$		
$r_6 = 10.175$	$d_6 = 1.49$	$n_{d4} = 1.80518$	$\nu_{d4} = 25.42$
$r_7 = 52.930$	$d_7 = $(Variable)		
$r_8 = \infty$ (Stop)	$d_8 = 0.65$		
$r_9 = 130.178$ (Aspheric)	$d_9 = 1.00$	$n_{d5} = 1.60311$	$\nu_{d5} = 60.64$
$r_{10}= -8.730$	$d_{10}= 0.34$		

$r_{11}=$ 4.132	$d_{11}=$ 3.55	$n_{d6}=1.61272$ $\nu_{d6}=58.72$
$r_{12}=$ -6.617	$d_{12}=$ 0.34	$n_{d7}=1.74077$ $\nu_{d7}=27.79$
$r_{13}=$ 3.048	$d_{13}=$ 1.46	
$r_{14}=$ -39.710	$d_{14}=$ 0.99	$n_{d8}=1.60342$ $\nu_{d8}=38.03$
$r_{15}=$ -7.754	$d_{15}=$(Variable)	
$r_{16}=$ 9.702	$d_{16}=$ 1.86	$n_{d9}=1.56384$ $\nu_{d9}=60.67$
$r_{17}=$ -12.781	$d_{17}=$ 2.85	
$r_{18}=$ ∞(Image Plane)		

Zooming Spaces

f	2.973	5.050	8.568
d_7	12.07	4.90	0.68
d_{15}	0.68	3.82	9.11

Aspherical Coefficients

5 th surface

$K = 0.000$

$A_4 = -1.62760 \times 10^{-3}$

$A_6 = 1.46118 \times 10^{-9}$

$A_8 = -2.79032 \times 10^{-6}$

$A_{10} = -7.03666 \times 10^{-9}$

9 th surface

$K = 0.000$

$A_4 = -3.86799 \times 10^{-4}$

$A_6 = -2.95260 \times 10^{-5}$

$A_8 = 7.94144 \times 10^{-6}$

$A_{10} = -5.69253 \times 10^{-7}$

Example 8

$$f = 3.293 \sim 5.609 \sim 9.524$$

$$F_{NO} = 2.31 \sim 2.93 \sim 4.00$$

$$\omega = 38.0° \sim 23.8° \sim 15.6°$$

$r_1 = 55.120$	$d_1 = 0.83$	$n_{d1} = 1.69680$	$\nu_{d1} = 55.53$
$r_2 = 10.332$ (Aspheric)	$d_2 = 3.00$		
$r_3 = -965.135$	$d_3 = 0.72$	$n_{d2} = 1.81600$	$\nu_{d2} = 46.62$
$r_4 = 6.176$	$d_4 = 2.35$		
$r_5 = 11.134$	$d_5 = 1.54$	$n_{d3} = 1.80518$	$\nu_{d3} = 25.42$
$r_6 = 66.559$	$d_6 =$ (Variable)		
$r_7 = \infty$ (Stop)	$d_7 = 0.31$		
$r_8 = 17.836$ (Aspheric)	$d_8 = 1.25$	$n_{d4} = 1.60311$	$\nu_{d4} = 60.64$
$r_9 = -12.214$	$d_9 = 0.38$		
$r_{10} = 4.809$	$d_{10} = 3.48$	$n_{d5} = 1.61272$	$\nu_{d5} = 58.72$
$r_{11} = -10.031$	$d_{11} = 0.38$	$n_{d6} = 1.72825$	$\nu_{d6} = 28.46$
$r_{12} = 3.365$	$d_{12} = 2.07$		
$r_{13} = 35.376$	$d_{13} = 1.24$	$n_{d7} = 1.51633$	$\nu_{d7} = 64.14$
$r_{14} = -13.694$	$d_{14} =$ (Variable)		
$r_{15} = 14.404$ (Aspheric)	$d_{15} = 1.73$	$n_{d8} = 1.56384$	$\nu_{d8} = 60.67$
$r_{16} = -11.239$	$d_{16} = 3.16$		
$r_{17} = \infty$ (Image Plane)			

Zooming Spaces

f	3.293	5.609	9.524
d_6	12.14	4.96	0.75

d_{14}	0.75	4.32	10.31

Aspherical Coefficients

2 nd surface

K = 0.000

$A_4 = -4.28951 \times 10^{-4}$

$A_6 = -1.40724 \times 10^{-6}$

$A_8 = 9.12064 \times 10^{-13}$

$A_{10} = -1.28146 \times 10^{-10}$

8 th surface

K = 0.000

$A_4 = -2.35699 \times 10^{-4}$

$A_6 = -4.89159 \times 10^{-6}$

$A_8 = 1.54420 \times 10^{-6}$

$A_{10} = -1.27205 \times 10^{-7}$

1 5 th surface

K = 0.000

$A_4 = -9.39428 \times 10^{-4}$

$A_6 = 5.60401 \times 10^{-5}$

$A_8 = -4.51224 \times 10^{-6}$

$A_{10} = 1.28590 \times 10^{-7}$

Example 9

$f = 2.378 \sim 4.040 \sim 6.854$

$F_{NO} = 2.36 \sim 2.96 \sim 3.99$

$\omega = 37.9° \sim 23.7° \sim 14.4°$

$r_1 = 16.595 \qquad d_1 = 0.60 \qquad n_{d1} = 1.69680 \quad \nu_{d1} = 55.53$

r_2 =	5.379	d_2 = 1.31	
r_3 =	14.644	d_3 = 0.52	n_{d2} =1.78590 ν_{d2} =44.20
r_4 =	4.611	d_4 = 0.05	n_{d3} =1.52555 ν_{d3} =52.45
r_5 =	3.785 (Aspheric)	d_5 = 1.48	
r_6 =	6.675	d_6 = 1.21	n_{d4} =1.80518 ν_{d4} =25.42
r_7 =	17.397	d_7 =(Variable)	
r_8 =	∞ (Stop)	d_8 = 0.51	
r_9 =	16.657 (Aspheric)	d_9 = 0.87	n_{d5} =1.60311 ν_{d5} =60.64
r_{10}=	-7.020	d_{10}= 0.27	
r_{11}=	2.842	d_{11}= 1.93	n_{d6} =1.61272 ν_{d6} =58.72
r_{12}=	-48.288	d_{12}= 0.27	n_{d7} =1.74077 ν_{d7} =27.79
r_{13}=	2.086	d_{13}= 1.19	
r_{14}=	-11.321	d_{14}= 0.74	n_{d8} =1.51633 ν_{d8} =64.14
r_{15}=	-5.077	d_{15}=(Variable)	
r_{16}=	21.219 (Aspheric)	d_{16}= 1.34	n_{d9} =1.56384 ν_{d9} =60.67
r_{17}=	-5.168	d_{17}= 2.28	
r_{18}=	∞(Image Plane)		

Zooming Spaces

f	2.378	4.040	6.854
d_7	9.30	3.79	0.54
d_{15}	0.54	2.72	6.38

Aspherical Coefficients

5 th surface

K = 0.000

$A_4 = -2.74462 \times 10^{-3}$

$A_6 = 6.30526 \times 10^{-9}$

$A_8 = -7.64294 \times 10^{-6}$

$A_{10} = -5.31771 \times 10^{-7}$

9 th surface

$K = 0.000$

$A_4 = -1.28741 \times 10^{-3}$

$A_6 = -1.41016 \times 10^{-4}$

$A_8 = 6.14338 \times 10^{-5}$

$A_{10} = -9.42124 \times 10^{-6}$

1 6 th surface

$K = 0.000$

$A_4 = -3.49985 \times 10^{-3}$

$A_6 = 3.51560 \times 10^{-4}$

$A_8 = -6.00944 \times 10^{-5}$

$A_{10} = 4.17522 \times 10^{-6}$

Example 1 0

$f = 1.975 \sim 2.213 \sim 5.703$

$F_{NO} = 2.32 \sim 2.42 \sim 4.00$

$\omega = 38.1° \sim 24.8° \sim 13.9°$

$r_1 = 11.948$	$d_1 = 0.50$	$n_{d1} = 1.69680$ $\nu_{d1} = 55.53$
$r_2 = 5.328$	$d_2 = 1.27$	
$r_3 = 30.813$	$d_3 = 0.45$	$n_{d2} = 1.69680$ $\nu_{d2} = 55.53$
$r_4 = 6.338$	$d_4 = 1.43$	
$r_5 = -10.493$	$d_5 = 0.41$	$n_{d3} = 1.88300$ $\nu_{d3} = 40.76$
$r_6 = -1954.465$	$d_6 = 0.60$	
$r_7 = -9.386$	$d_7 = 0.78$	$n_{d4} = 1.80518$ $\nu_{d4} = 25.42$

r_8 =	-5.266	d_8 =(Variable)	
r_9 =	∞ (Stop)	d_9 = 0.77	
r_{10}=	2.711 (Aspheric)	d_{10}= 0.92	n_{d5} =1.60311 ν_{d5} =60.64
r_{11}=	-8.179	d_{11}= 0.99	
r_{12}=	59.968 (Aspheric)	d_{12}= 0.46	n_{d6} =1.61272 ν_{d6} =58.72
r_{13}=	-5.078	d_{13}= 0.23	n_{d7} =1.74077 ν_{d7} =27.79
r_{14}=	1.993	d_{14}= 0.58	
r_{15}=	3.332	d_{15}= 0.50	n_{d8} =1.60342 ν_{d8} =38.03
r_{16}=	24.187	d_{16}=(Variable)	
r_{17}=	40.169 (Aspheric)	d_{17}= 2.06	n_{d9} =1.56384 ν_{d9} =60.67
r_{18}=	-3.967	d_{18}= 2.52	
r_{19}=	∞(Image Plane)		

Zooming Spaces

f	1.975	2.213	5.703
d_8	8.58	7.16	0.45
d_{16}	0.23	0.57	5.30

Aspherical Coefficients

10th surface

K = 0.000

A_4 =-6.90936$\times 10^{-3}$

A_6 =-2.33335$\times 10^{-4}$

A_8 =-3.03337$\times 10^{-4}$

A_{10}= 4.13358$\times 10^{-5}$

12th surface

K = 0.000

A_4 = 3.78672$\times10^{-3}$

A_6 =-7.39104$\times10^{-4}$

A_8 = 9.77894$\times10^{-4}$

A_{10}= 6.87146$\times10^{-6}$

1 7 th surface

K = 0.000

A_4 =-1.32840$\times10^{-2}$

A_6 =-5.56828$\times10^{-4}$

A_8 =-1.76574$\times10^{-4}$

A_{10}= 5.44032$\times10^{-5}$

Example 1 1

f = 2.635 ~ 4.487 ~ 7.620

F_{NO}= 2.31 ~ 2.93 ~ 4.00

ω = 37.9 ° ~ 24.0 ° ~ 15.8 °

r_1 = 12.619	d_1 = 0.57	n_{d1} =1.69680	ν_{d1} =55.53
r_2 = 4.093	d_2 = 2.07		
r_3 = 15.510	d_3 = 0.42	n_{d2} =1.78590	ν_{d2} =44.20
r_4 = 4.063 (Aspheric)	d_4 = 1.50		
r_5 = 8.342	d_5 = 1.27	n_{d3} =1.80518	ν_{d3} =25.42
r_6 = 61.897	d_6 =(Variable)		
r_7 = ∞ (Stop)	d_7 = 0.42		
r_8 = 5.236 (Aspheric)	d_8 = 2.36	n_{d4} =1.60311	ν_{d4} =60.64
r_9 = -11.121	d_9 = 0.30		
r_{10}= 5.726	d_{10}= 2.08	n_{d5} =1.61272	ν_{d5} =58.72
r_{11}= -6.055	d_{11}= 0.30	n_{d6} =1.74077	ν_{d6} =27.79
r_{12}= 2.955	d_{12}= 2.06		

$r_{13}=$ 9.461 $d_{13}=$ 0.61 $n_{d7}=1.60342$ $\nu_{d7}=38.03$

$r_{14}=$ 10391.820 $d_{14}=$(Variable)

$r_{15}=$ 6.809 (Aspheric) $d_{15}=$ 1.07 $n_{d8}=1.56384$ $\nu_{d8}=60.67$

$r_{16}=$ -29.066 $d_{16}=$ 2.38

$r_{17}=$ ∞(Image Plane)

Zooming Spaces

f	2.635	4.487	7.620
d_6	9.05	3.73	0.60
d_{14}	0.60	3.50	8.36

Aspherical Coefficients

4 th surface

$K = 0.000$

$A_4 = -2.63379 \times 10^{-3}$

$A_6 = -2.53552 \times 10^{-5}$

$A_8 = -9.03111 \times 10^{-6}$

$A_{10} = -3.56959 \times 10^{-8}$

8 th surface

$K = 0.000$

$A_4 = -1.28320 \times 10^{-3}$

$A_6 = -2.03529 \times 10^{-5}$

$A_8 = -6.76960 \times 10^{-7}$

$A_{10} = -1.22132 \times 10^{-8}$

1 5 th surface

$K = 0.000$

$A_4 \ =-1.23704 \times 10^{-3}$

$A_6 \ = \ 1.72577 \times 10^{-4}$

$A_8 \ =-2.38467 \times 10^{-5}$

$A_{10}= \ 1.22142 \times 10^{-6}$

Figs. 12(a), 12(b) and 12(c) are aberration diagrams for Example 1 upon focused at infinity, where (a) shows aberration curves at the wide-angle end, (b) aberration curves at the intermediate settings, and (c) aberration

5   curves at the telephoto end. In these drawings, SA, AS, DT and CC represent spherical aberrations, astigmatism, distortion and chromatic aberrations of magnification, respectively.

Set out below are the values for conditions (1) to (1)

10   in Examples 1 to 11.

Ex.	Cond. (1)	Cond. (2)	Cond. (3)	Cond. (4)	Cond. (5)
1	0.3 (h=5)	-0.19 (h=4)	0.05 (h=5)	1.10	1.62
2	0.1 (h=4)	-0.05 (h=3.7)	***	1.67	1.26
3	0.2 (h=4)	-0.06 (h=4)	***	1.30	1.26
4	0.2 (h=6)	-0.1 (h=4)	***	1.20	2.45
5	0.4 (h=5)	***	0.07 (h=5)	1.18	1.81
6	***	-0.3 (h=3)	***	1.14	1.23
7	0.3 (h=3)	***	-0.001 (h=3)	1.18	1.81
8	0.2 (h=4.5)	-0.06 (h=2.3)	***	1.20	2.45
9	0.4 (h=3)	-0.08 (h=1.5)	0.1 (h=3)	1.10	1.62
10	***	-0.2 (h=1.2)	***	1.14	1.23
11	0.2 (h=2.5)	-0.02 (h=1.6)	***	1.30	1.26

The bracketed h added after the values of conditions (1),

25   (2), (3) and (7) represents the heights of the figured out points from the optical axis, and *** shows that the condition is not used in the example.

Ex.	Cond. (6)	Cond. (7)	Cond. (8)	Cond. (9)	Cond. (10)
1	4.17	-0.02 (h=2.2)	-0.980	3.208	7.10
2	6.35	-0.03 (h=2.5)	-0.524	4.431	6.69
3	4.95	-0.01 (h=2.8)	-0.673	4.071	6.90
4	4.59	-0.01 (h=2.5)	-0.784	3.642	9.24
5	4.48	-0.01 (h=2.5)	-0.900	3.702	10.48
6	4.34	-0.09 (h=2.8)	-1.055	2.957	2.03
7	4.48	-0.03 (h=2)	-0.901	3.702	10.44
8	4.59	-0.01 (h=2)	-0.784	3.644	9.16
9	4.17	-0.02 (h=1.2)	-0.980	3.211	7.15
10	4.34	-0.7 (h=1.2)	-1.059	2.967	2.00
11	4.95	-0.04 (h=1)	-0.673	4.065	6.93

The aforesaid zoom lens systems according to the present invention may be used with various phototaking systems using electronic image pickup devices such as CCDs, and CMOS sensors, as embodied below.

The zoom lens system according to the present invention may be used on various image pickup systems using electronic image pickup devices such as CCD or CMOS sensors, as embodied below.

An electronic cameral wherein the zoom lens system of the present invention is incorporated in the form of an objective optical system is shown in Figs. 14 to 16. Fig. 14 is a front perspective view illustrative of the appearance of an electronic camera 200, and Fig. 15 is a rear perspective view illustrative of the electronic camera 200. Fig. 16 is a sectional view illustrative of the construction of the electronic camera 200. As shown in Figs. 14 to 16, the

electronic camera 200 comprises a phototaking optical system

202 including a phototaking optical path 201, a finder

optical system 204 including a finder optical path 203, a

shutter 205, a flash 206 and a liquid crystal display monitor

5   207. Upon pressing down the shutter button 205 located on

the upper portion of the camera 200, phototaking occurs

through an objective lens system 12 comprising the instant

zoom lens system (roughly shown) located as a phototaking

objective optical system. An object image formed through the

10   phototaking optical system is then formed on the image pickup

plane of an image pickup device chip 62 such as a CCD via an

IR (infrared ray) cut filter 80.

The IR cut filter 80 is additionally added onto the

image pickup device chip 62 to form an integral image pickup

15   unit 60, which can be mounted on the rear end of a lens

barrel 13 of the objective 12 in one-touch simple operation.

Thus, any centering operation of the objective 12 with

respect to the image pickup device chip 62 and any surface-

spacing regulation operation can be dispensed with, resulting

20   in commercial merits such high camera fabrication capability

and cost reductions. The front end of the lens barrel 13 is

provided with a cover glass 14 for the protection of the

objective 12. It is here noted that the zoom lens driving

mechanism in the lens barrel 13 is not shown.

25   The object image sensed by image pickup device chip 62

is displayed as an electronic image on the liquid crystal

display monitor 207 located on the back side of the camera

via processing means 208 electrically connected to a terminal

66. This processing means 208 may also control recording means 209 for recording the object image phototaken through the image pickup device chip 62 in the form of electronic information. It is here noted that the recording means 209

5   may be provided as a memory mounted on the processing means 208 or in the form of a device electrically connected to the processing means 208 to electronically write the information into a magnetic recording medium such as a floppy disk or smart media.

10   Further, the finder optical system 204 having a finder optical path 203 comprises a finder objective optical system 210, a Porro prism 211 for erecting the object image formed through the finder objective optical system 210 and an eyepiece 212 for guiding the object image to the eyeball E of

15   an observer. The Porro prism 211 is divided into a front and a rear block with an object image-forming surface located between them. On this surface there is provided a field frame-of-view frame 213. The Porro prism 211 comprises four reflecting surfaces to erect the object image formed through

20   the finder objective optical system 210.

     To reduce the number of parts and achieve compactness and cost reductions, the finder optical system 204 may be removed from the camera 200. In this case, the observer carries out phototaking while looking at the liquid crystal

25   monitor 207.

     Shown in Figs. 20 to 22 is a personal computer that is one example of the information processor in which the zoom lens system of the invention is incorporated in the form of

an objective optical system. Fig. 20 is a front perspective
views of an uncovered personal computer 300, Fig. 21 is a
sectional view of a phototaking optical system 303 mounted on
the personal computer 300, and Fig. 22 is a side view of Fig.

5 20. As depicted in Figs. 20 to 22, the personal computer 300
comprises a key board 301 for allowing an operator to enter
information therein from outside, information processing and
recording means (not shown), a monitor 302 for displaying the
information to the operator and a phototaking optical system

10 303 for phototaking an image of the operator per se and
images of operator's surroundings. The monitor 302 used
herein may be a transmission type liquid crystal display
device designed to be illuminated by a backlight (not shown)
from the back side, a reflection type liquid crystal display

15 device designed to display images by reflecting light from
the front side, a CRT display or the like. As shown, the
phototaking optical system 303 is built in the right upper
portion of monitor 302. However, it is to be understood that
the phototaking optical system 303 may be positioned

20 somewhere on the periphery of monitor 302 or keyboard 301.

The phototaking optical system 303 includes on a
phototaking optical path 304 an objective lens system 112
comprising the zoom lens system 12 of the invention (roughly
shown) and an image pickup device chip 62 for receiving an

25 image. These are built in the personal computer 300.

An IR cut filter 80 is additionally added onto the image
pickup device chip 62 to form an integral image pickup unit
60, which can be mounted on the rear end of a lens barrel 13

of the objective 12 in one-touch simple operation. Thus, any centering operation of the objective 12 with respect to the image pickup device chip 62 and any surface-spacing regulation operation can be dispensed with, resulting in

5 commercial merits such high camera fabrication capability and cost reductions. The front end of the lens barrel 13 is provided with a cover glass 14 for the protection of the objective 12. It is here noted that the zoom lens driving mechanism in the lens barrel 13 is not shown.

10 An object image sensed by the image pickup device chip 62 is entered from a terminal 66 in the processing means in the personal computer 300, and displayed as an electronic image on the monitor 302. Shown in Fig. 20 as an example is a phototaken image 305 of the operator. It is possible to

15 display the image 305, etc. on a personal computer at the other end on a remote place via an internet or telephone line.

Illustrated in Fig. 23 is a telephone handset that is one example of the information processor in which the zoom

20 lens system of the invention is built in the form of a phototaking optical system, especially a convenient-to-carry portable telephone handset. Fig. 23(a) is a front view of a portable telephone handset 400, Fig. 23(b) is a side view of handset 400 and Fig. 23(c) is a sectional view of a

25 phototaking optical system 405. As depicted in Figs. 23(a) to 23(c), the telephone handset 400 comprises a microphone portion 401 for entering an operator's voice therein as information, a speaker portion 402 for producing a voice of a

person on the other end, an input dial 403 allowing the

operator to enter information therein, a monitor 404 for

displaying phototaken images of the operator and the person

on the other end and information such as telephone numbers, a

5   phototaking optical system 405, an antenna 406 for

transmitting and receiving communication waves and a

processing means (not shown) for processing image

information, communication information, input signals, etc.

The monitor 404 used herein is a liquid crystal display

10   device. The arrangement of these parts is not necessarily

limited to that illustrated. The phototaking optical system

405 includes on a phototaking optical path 407 an objective

lens system 12 comprising the zoom lens system (roughly

illustrated) of the invention and an image pickup device chip

15   62 for receiving an object image. These are built in the

telephone handset 400.

An IR cut filter 80 is additionally added onto the image

pickup device chip 62 to form an integral image pickup unit

60, which can be mounted on the rear end of a lens barrel 13

20   of the objective 12 in one-touch simple operation. Thus, any

centering operation of the objective 12 with respect to the

image pickup device chip 62 and any surface-spacing

regulation operation can be dispensed with, resulting in

commercial merits such high camera fabrication capability and

25   cost reductions. The front end of the lens barrel 13 is

provided with a cover glass 14 for the protection of the

objective 12. It is here noted that the zoom lens driving

mechanism in the lens barrel 13 is not shown.

The object image sensed by the image pickup device chip 62 is entered from a terminal 66 in a processing means (not shown), and displayed as an electronic image on the monitor 404 and/or a monitor on the other end. To transmit an image

5   to a person on the other end, the processing means includes a signal processing function of converting information about the object image received at the image pickup element chip 162 to transmittable signals.

As can be understood from the foregoing, the present

10 invention makes it possible to provide a zoom lens system having a zoom ratio of about 3, a wide field angle on its wide-angle side and a small F-number as well as a lens layout enabling satisfactory image-formation capability to be obtained. This zoom lens system is excellent in fabrication

15 capability, and is particularly suitable for use on compact portable information terminals.